FORESTRY

THE JOURNAL OF THE SOCIETY OF FORESTERS OF GREAT BRITAIN

Edited by C. W. SCOTT

VOLUME XXI : NUMBER 2

1947

Price
Seven Shillings and Sixpence

Published by the
OXFORD UNIVERSITY PRESS
LONDON: GEOFFREY CUMBERLEGE
AMEN HOUSE, E.C.4
1948

FORESTRY

THE JOURNAL OF THE SOCIETY OF FORESTERS OF GREAT BRITAIN

Edited by C. W. SCOTT

VOLUME XXI, No. 2

1947

Published by the

OXFORD UNIVERSITY PRESS

LONDON : GEOFFREY CUMBERLEGE

AMEN HOUSE, E.C. 4

1948

FORESTRY

CONTENTS OF VOLUME XXI, NUMBER 2

The Place of Compound Interest in Forest Finance. By W. E. HILEY . 137

Forest Fire Protection in Germany. By G. B. RYLE 141

The Effect of Atmospheric Humidity on the Development of Fires. By J. BRYAN 146

Scots Pine Regeneration in a New Forest Inclosure (*Pinus sylvestris* L.). By E. W. JONES 151

Volume Estimation of Standing Timber by Sampling. By D. J. FINNEY . 179

Behaviour of Corsican Pine Stock Following Different Nursery Treatments (*Pinus nigra* var. *calabrica* Schneid.). By M. C. RAYNER . . . 204

Preliminary Note on a Disease of Sitka Spruce in Cairnhill Plantation, Durris, Kincardineshire (*Picea sitchensis* Carr.). By E. V. LAING . 217

Pissodes validirostris Gyll., in Shoots of *Pinus sylvestris* L. By MYLES CROOKE 221

Society's and Other News 227

REVIEWS

Breaking New Ground (GIFFORD PINCHOT). By G. B. RYLE . . . 233

The Earth's Face (Landscape and its relation to the health of the soil) (EHRENFRIED PFEIFFER). By SIR HAROLD GLOVER 234

Handbook of the Trees of the Northern States and Canada (ROMEYN B. HOUGH). By F. K. MAKINS 234

Timber, its Structure and Properties (H. E. DESCH). By B. J. RENDLE. . 235

Decay of Timber and its Prevention (K. ST. G. CARTWRIGHT and W. P. K. FINDLAY). By W. R. DAY 236

Über die Physiologie ligninabbauender Bodenhymenomyzeten. Studien an Schwedischen Marasmius-Arten (GÖSTA LINDEBERG). By IDA LEVISOHN 238

Der Einfluss von Waldstreuextrakten auf das Wachstum von Bodenpilzen, mit besonderer Berücksichtigung der Wurzelpilze von Bäumen (ELIAS MELIN). By IDA LEVISOHN 239

Fifth British Empire Forestry Conference. Great Britain, 1947. Summary Report, Resolutions and Reports of Committees. By the Editor . 241

NOTICES

The Scots Pine. An Introduction to Forestry. By HARRY WATSON . 246

Woodland Mosses. (Forestry Commission Booklet No. 1.) By H. WATSON 246

Fire Control Notes, Vol. 8, No. 4, Oct. 1947. (Forest Service, U.S. Dept. of Agriculture, Washington) 246

Extracts from *The Forestry Chronicle*, *Forestry Abstracts*, &c. . . 247

PRINTED IN GREAT BRITAIN

SOCIETY OF FORESTERS OF GREAT BRITAIN

THIS SOCIETY was formed in 1925 and adopted its first Constitution at Oxford in 1926. The object of the Society is to advance and spread in Great Britain the knowledge of technical forestry in all its aspects.

The Society consists of Professional and Ordinary Members. Professional membership is divided into two orders:

FELLOWS, being holders of a degree or diploma in forestry, and subjects of the British Crown, but not necessarily resident in Great Britain; and

ASSOCIATES, being subjects of the British Crown resident in Great Britain, whole-time foresters, and not eligible for Fellowship. They pay a less subscription than Fellows but have almost equal privileges.

Ordinary membership is open to persons not eligible for either of the above.

Office-bearers and Councillors are nominated by Professional Members, and in the event of competition for any office a postal ballot of the whole Professional membership is held. The following were elected to serve in 1947:

President:	W. H. GUILLEBAUD, B.A., Forestry Commission.
Vice-President:	OWEN J. SANGAR, M.C., Forestry Commission.
Editor of Journal:	C. W. SCOTT, O.B.E., D.F.C., B.SC., 'Downhill', Ellesborough Road, Wendover, Aylesbury, Bucks.
Business Editor:	J. ALAN B. MACDONALD, 35 Manor Place, Edinburgh, 3.
Secretary and Treasurer:	R. ANGUS GALLOWAY, M.C., B.SC., Solicitor, 8 Rutland Square, Edinburgh, 1. Tel. No., Edinburgh 23842.
Auditor:	D. L. FERGUSON, 25 Drumsheugh Gardens, Edinburgh, 3.
Councillors:	C. A. CONNELL, M.A. E. V. LAING, M.A., D.SC. C. H. THOMPSON, M.A., DIP. FOR. A. H. GOSLING, B.SC. RAY BOURNE, M.A. B. J. RENDLE, B.SC.

THE SOCIETY AND ITS JOURNAL

THE IMPORTANCE OF FORESTRY is being realized more and more in Great Britain. The number of foresters is increasing steadily, and a forestry profession is gradually being built up. It is intended that this Society should be representative of the profession. Those who are not engaged in the practice of forestry or the allied sciences are cordially invited to join the Society as Ordinary Members.

SUBSCRIPTIONS are:

Fellows and Ordinary Members: £1. 1*s*. 0*d*. annually or £10. 10*s*. 0*d*. for Life.
Associates: 10*s*. 6*d*. annually.

THE SOCIETY'S JOURNAL, called *Forestry*, is usually published twice a year, in June and December. It provides a means for the publication of the results of practice and research both in the growing of timber and in its utilization, including such basic sciences as forest physiology and ecology, forest soils, wood structure, and timber physics, and allied sciences such as forest entomology and forest mycology.

CONTRIBUTIONS may be accepted from members and others resident either in Great Britain or abroad. They should be sent to the editor, C. W. Scott, 'Downhill', Ellesborough Road, Wendover, Aylesbury, Bucks. No article should be submitted which is being offered to any other journal for prior or simultaneous publication. Articles should be typewritten, and must be in a final form suitable for publication. References to literature should be collected at the end of the paper, and arranged alphabetically according to author's name, and numbered. In the text each reference should be indicated by its number enclosed in brackets. Each article should conclude with a summary. It should give the methods, extent of material, observations, and results, but should be brief and not exceed 3 per cent. of the original. It is understood that the author waives any copyright or translation rights in such summaries and that their reproduction in other publications will be permitted, subject to the source being duly acknowledged. Twenty reprints of the article will be sent free to each contributor and a reasonable number may be purchased by the contributor if ordered when the proofs are returned. The Society as a body takes no responsibility for the views expressed by contributors.

Forestry is sent free to members of the Society; others may register as subscribers by application to the Secretary, R. Angus Galloway, 8 Rutland Square, Edinburgh, 1.

SOCIETY'S MEDAL. For the rules concerning the award of this Medal see vol. xx, pp. 80–1.

THE PLACE OF COMPOUND INTEREST IN FOREST FINANCE

By W. E. HILEY

IN a recent article entitled 'A Problem of Forest Finance'[1] Mr. W. L. Taylor has challenged 'the bogy of compound interest . . . in the theory of forest finance'. It is an interesting article with the substance of which I largely agree, and I should not have attempted to reply to it had I not found that certain candidates in forestry examinations have already lost marks through confused thinking which has been directly induced by some of the sentences in the article.

Mr. Taylor has wisely stressed the benefits, other than those which are purely financial, which are derived from the making and maintenance of forests, and he quite rightly points out that owing to these benefits, which cannot be assessed in money, a nation or an individual owner may justly invest money in forestry although the financial return from this investment is lower than might be expected on the Stock Exchange. The economic man is an abstraction, and as all of us spend money purely for enjoyment, so the business man may justly spend some money on his business which yields no direct financial return but increases his own delight in his work and provides pleasure for his employees or the general public.

Unfortunately the article confuses this admirable thesis with the question of whether, when making financial calculations about forestry, we should or should not introduce compound interest, and to any but a very careful reader the author might seem to imply that simple interest would be a more appropriate basis. Thus, 'For one reason or another our railways are said to-day to be over-capitalized, that is, on the basis of cash revenue they fail to pay *simple* interest on all capital cost. Imagination staggers at the picture of current railway accounts if the capital sunk in the past 100 years were all chargeable at *compound* interest rates.' We are not concerned here with the question of whether railways are over-capitalized or not. What matters to an investor is whether he obtains a dividend on his investment. If the dividend is paid annually he can calculate the rate of return quite simply in terms of simple interest. If, however, the income to be derived from the investment is deferred for many years, then the element of compound interest necessarily comes into his calculations. The difference is readily seen in comparing a bond, which yields income every year, with a national savings certificate, which only yields a lump sum at the end of ten years. The competent investor will work out the rate of compound interest which a national savings certificate earns, and he rightly expects to receive a larger return at the end of the ten years because in each intervening year the Government has kept the interest that was due to him and has had the use of it until the end of the period.

See p. 231 for Mr. Taylor's reply.

[1] *Forestry*, vol. xx, p. 3, 1946.

Actually the kind of calculation which we use in forestry is equally applicable to a railway. During the period while a railway is being constructed no profit is earned; and if the money required each year for wages and materials is borrowed from a bank the debt to the bank will automatically increase by the amount drawn each year plus compound interest. When construction is completed and profits are earned, the interest on the debt can be paid annually and compound interest no longer applies. In the same manner, when plantations are being established a debt is created which increases by compound interest; but when the plantations become self-supporting—and, particularly, when something approaching a normal forest has been created—then the interest on the debt can be paid annually and it is no longer increased by compound interest. The difficulty with forestry, especially with an afforestation scheme which starts *de novo*, is that the building-up period is very protracted so that the debt grows with compound interest for a very long time.

Although in these instances the bank debt rises by compound interest, it is in fact charged as simple interest each year on the amount of the debt at the beginning of the year. There is thus no essential difference between compound and simple interest; if you cannot pay interest on the debt each year, then you have to pay interest on the amount you should have paid as interest; and so the debt grows.

Those of us who are frequently working out financial returns from forestry come to see that compound interest is the only rational basis for such computations, that is, it is the only basis which will yield mutually consistent results; and to such students it appears that the law of compound interest is as immutable as the law of gravity. It might be much pleasanter to assume that attraction due to gravity varied inversely as the distance between two objects, instead of inversely as the square of the distance between two objects. Not only is the first assumption wrong, but if one attempted to work astronomical calculations on such a basis the results would be self-contradictory. It is difficult to show quite simply that compound interest is a necessary basis for calculation, and that calculations with simple interest would lead to chaotic results, but the two following examples may go some way towards it.

In the first example we will envisage a world in which wages and prices remain constant: and a perfectly accurate calculation on the lines of the Faustmann formula that money invested in planting Douglas fir will yield 4 per cent. compound interest on a 50-year rotation. We will suppose that we plant 10 acres a year for 50 years, so that at the end of this period we have a normal forest of 500 acres. We shall then receive a fixed annual income from the forest. If all the money required for creating this normal forest, after crediting receipts from thinnings, &c., were borrowed from the bank at a fixed rate of 4 per cent. compound interest, we should at the end of 50 years have a debt at the bank which represents the capital cost of the forest.

Calculations show that, under these conditions, the net annual return from the normal forest 50 years hence would be just sufficient to pay 4 per cent. *simple interest* on this debt.

In this example the owner of the forest makes neither profit nor loss. This is the correct result, for, if we borrow money at 4 per cent. and reinvest it at 4 per cent., we should not expect to make a profit. We only make a profit if in fact we earn more than 4 per cent. from the use of the capital; and this is what a forester would hope to do, either through the efficiency of his management or because, as will probably happen, the price of timber will rise in the course of 50 years.

In the second example let us suppose that you are offered an investment for £100 on the understanding that there shall be no annual return, but that you may choose either (*a*) to have back £324 at the end of 30 years, with the option of reinvestment on the same terms for another 30 years, or (*b*) to receive back £589 at the end of 60 years. Which of these alternatives would you choose? If you work them out on a basis of simple interest, alternative (*a*) yields a profit of £224 in 30 years, or about 7·5 per cent. per annum; whereas (*b*) yields a profit of £489 in 60 years, which is equal to about 8·2 per cent. per annum. So (*b*) appears preferable to (*a*). If, on the other hand, you work them out on a compound-interest basis, you will find that (*a*) yields 4 per cent. compound interest and (*b*) yields 3 per cent. compound interest, so that basis (*a*) appears preferable.

Confronted with this choice the wise investor will take the £324 at the end of 30 years and reinvest this £324 for another 30 years on the same terms. Then at the end of 60 years he will have £1,050, which is obviously much more favourable to him than the £589 which is received by the person who chooses alternative (*b*).

In this example the investor who thought in terms of simple interest would have been completely misled and would have earned much less profit than the investor who thought in terms of compound interest, and whereas the compound-interest computation gives a true picture of what is happening, the simple-interest calculation is meaningless.

In my example I have chosen the periods of 30 years and 60 years because it is the kind of choice that may be made in forest practice. Our £100 might be used by our agent in planting conifers; and he might cut these conifers for pitprops on a rotation of 30 years and reinvest the money in buying more land and planting more trees, to be felled at the end of a further 30 years for pitprops; or he might work on a rotation of 60 years and grow the trees for timber. The return of £324 after 30 years, or £589 after 60 years, are the sort of returns that might be derived from these alternative rotations. If one thinks in terms of simple interest, the timber rotation appears financially more attractive than the pitwood rotation. If, however, one calculates in terms of compound interest, the pitprop rotation appears financially better. We have already seen that if the proceeds from the pitprops were invested in planting more land, the financial return would be much more attractive than the return from growing timber.

In practical forestry our calculations are much more complicated than this because the money is not all spent at the beginning of the period, but expenditure is spread throughout the rotation, and income may be expected at intervals from thinnings. The Faustmann formula has been devised to meet this difficulty. The principle, however, is just as simple as in the example I have given.

The Government at some time may ask how much it would cost to grow our own supply of pitprops, or, alternatively, how much to grow our timber needs. If the rate of interest is fixed by the rate at which they can borrow, a cost of production on the assumption of fixed wages can be approximately worked out for each of these, but all these calculations must inevitably be based on compound interest, not on simple interest, otherwise the results will be completely misleading.

Mr. Taylor's article refers to another complication, namely, the fact that the rate of interest at which the Government can borrow varies from time to time. This certainly makes it more difficult to estimate future costs with accuracy, but it has no bearing whatever on the question of whether we should use compound interest or simple interest in our calculations.

The comparison between the pitprop rotation and the timber rotation provides an example of another aspect of the problem. Both the grower and the public derive more pleasure from looking at big trees than small trees. Though this additional pleasure cannot be expressed in money, it may rightly induce the owner, whether a private owner or the State, to grow his trees for timber rather than for pitprops, although he has calculated that pitprops would yield a higher rate of interest on the money invested. This is one of the imponderables about which Mr. Taylor writes so well, and I do not wish in any way to undervalue the importance of these imponderables in forestry. My argument is purely that when we are making financial calculations we must perforce use compound interest.

Mr. Taylor concludes his article with the sentence, 'Worship at the shrine of compound interest can, it seems, be carried too far'. If he had written, instead, 'Worship at the shrine of *financial profit* can, it seems, be carried too far', we should all have agreed with him; and he would not have led foresters into a confused hope that, after all, their calculations might be made without compound interest.

From the national point of view, however, the question of profit is less important than an endeavour to secure national objectives with as little expenditure as is reasonable in land, labour, and materials. Let us suppose that the national objective is to supply from home sources three-quarters of our pitprop needs and half our timber needs. It is probable that such an objective can be reached more economically on good land than on bad; and it can certainly be attained more quickly. We have also some latitude of choice over the species we plant and methods of cultivation. Calculations, with such data as are available, can be used to assess the relative cost of different methods of attaining this national objective, and such calculations are an essential ingredient in formulating an intelligent policy. In these calculations money is used as the integrating denominator for the value of labour and land (two crucial shortages) as well as materials, and compound interest provides the correct balancing factor for time (which, as the Lord President of the Council has recently pointed out, may be a still more crucial shortage).

Thus compound interest is not a shrine at which we worship but a useful method of working which allows a more correct assessment than would otherwise be possible of the relative merits of alternative policies.

FOREST FIRE PROTECTION IN GERMANY

AN EXAMINATION IN REGIERUNGS BEZIRK LÜNEBURG

(914 Military Government)

By G. B. RYLE

(*Forestry Commission and formerly of the North German Timber Control, Control Commission, Germany*)

DURING the forest year 1945–6 forest fires in Regierungs Bezirk Lüneburg did damage to 699 hectares of woodland. It was evident from attendance at more than one of these outbreaks that the standard of fire protection and of fire-fighting had sadly deteriorated during and since the war years through deficiencies in transport, equipment, and in the physical and moral standard of the population. It was thought desirable to carry out a brief inspection on behalf of the North German Timber Control to ascertain in what degree, if any, British Military Government could aid the German Forst und Holzwirtschaft to improve its technique and bring itself back to the efficiency attained before 1939. Comparison with British Forestry Commission technique was also borne in mind. This inspection was carried out jointly with Major Parkinson of the Public Safety (Fire) Branch of 914 Military Government, Lüneburg.

Regierungs Bezirk Lüneburg, the territory then under the writer's control, extends over an area of 1,134,291 hectares, of which 310,461 hectares are classed as forest. It is generally a very flat terrain with a dry sandy soil, and the main forest crop of Scots pine carries an over-preponderance of the younger age classes, much of this being densely sown thicket, unthinned and unbrashed. The fire risk is thus a severe one.

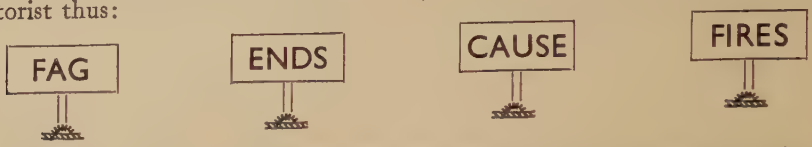
During the year there had been eighty-five recorded forest fires, and certainly there had been many others on private forests which were not officially notified to the German State department. These fires originated as follows:

9 caused by railway engines.
9 caused by destruction of ammunition dumps.
33 caused by carelessness.
34 fires were untraced as to origin.

There is no record as to the nationality of the persons who caused the thirty-three 'careless' fires.

The conditions generally strike one as being very similar to those in our own Thetford Chase forests, or rather as they will be there in the next generation. In Germany, however, there is an entirely 'forest-minded' population, and it is sadly notable that the only placards warning the public about the danger of forest fires are painted in English for the education of British occupation troops. A very striking form of notice consists of a series of boards stuck

up at about 50-yard intervals along the main roads and facing the oncoming motorist thus:



The German Forstmeisters say, and one can well believe them, that there is no need to warn their own people of the danger, as they are brought up from childhood to protect their forests.

Regierungs Bezirk Lüneburg is divided into nine Land Kreise, which may be likened roughly to our own Rural District Council governmental areas, and two Stadt Kreise similar to our Urban Districts.

The Forest Officers' charges (*Forstamte*) do not necessarily correspond territorially with the Kreis boundaries—one Forstamt may spread over the bounds of two or more Kreise, according to the layout of the large forest areas—but for each Kreis there is a senior officer or Kreis Forstmeister, who in addition to having charge of a Forstamt also has certain forest administrative responsibilities pertaining to the whole of the Kreis in which he resides. Amongst these duties there falls upon him the responsibility of administering the forest fire-protection system of the whole Kreis.

For fire-*fighting* all woods are treated alike, entirely irrespective of whether they be State owned, privately owned, church, corporation, or communal forests; but there is no compulsion upon a private forest owner to adopt efficient fire-*protective* measures, and it is notable that private forests, even where they adjoin extensive State forests, may be comparatively unprotected.

Land Kreis Soltau, comprising in all 90,156 hectares and containing 29,757 hectares of forest, was selected at random as a typical territory to examine. Oberforstmeister Reineke, who administers on the German side the whole of Regierungs Bezirk Lüneburg, and Kreis Forstmeister Meier of Soltau were helpful in giving all information and staging an interesting demonstration.

The forests are reasonably well split up by cultivated rides which are tractor-ploughed annually, and in this sandy soil they break down into a good clean tilth. Generally they strike one as being too narrow for safety, and where they traverse well-grown thicket forest or mature (thinned) crops they would be of small value. Only exceptionally and in very large forest areas does one find 90-metre breaks and these are commonly overgrown with heather. Hardwood firebelts of birch are common, mainly alongside public roads and less regularly as breaks in the actual forest. They have received no special treatment since planting and are admitted to be of more aesthetic than practical protective value. In fact an earlier requirement that the majority of them should be felled immediately for meeting in part the huge winter's fuelwood demand was greeted by Reineke with no regrets whatever. It was considered that the retention of a scattering of seed trees would suffice to ensure the felled strips becoming quickly regenerated by a more valuable dense low-storey thicket.

The practice and theory of the railway fire-breaks were extremely doubtful

and illustrated clearly the German's hatred of wasting a square inch of ground. On the particular length of railway examined an extensive fire had recently occurred, but it was carefully explained that the system had not been completely maintained there during the last stage of the war and had thus become ineffective. The layout of the system is to leave the strip of about 6 metres or less immediately adjacent to the permanent way to be scythed periodically. In this case it had been 'left to nature' and was densely clad with *Calluna* of about 4 years' growth. Beyond this a strip only 2 metres wide is hand cultivated down to the bare sandy soil and so kept in clean condition annually. Another similar 2-metre strip is cultivated some 10 metres farther back and these two clean lines are joined by cross cultivations about every 50 metres, thus dividing the belt into isolated rectangles. Each rectangle is then planted with pine to be maintained on a short rotation and cleaned and pruned as soon as it reaches thicket stage. Its function is to act as a spark arrester, any falling embers dropping harmlessly on to the clean ground beneath or at the worst lighting low vegetation and causing a small fire which would be confined within one of the rectangular patches. In practice it was found that these young thicket belts had not been cleaned and the underwood of dead branches would form an admirable fire tinder. No 'second line of defence' in the form of a wide fire-break parallel with the railway through the main forest crop, at, say, 50 metres distance, was normally formed. In this country where the soil is of an entirely poor dry sand the formation of less inflammable spark-arresting belts than pine was considered impracticable, though alder or red oak might be used under better soil conditions. It was agreed that the railway fire risk had become very much greater since the war on account of the poor quality of coal now being used and the impossibility of employing efficient spark arresters to function with the powdery brown-coal fuel.

The fire-patrol system was reasonably efficient and comprised a team of mobile men, generally on push-cycles, and a good system of fire-look-out stations. In this flat country the look-out stations are necessarily all of the tall trestle pylon type, properly triangulated, and they can cover immense areas efficiently. Two stations examined were found to be so old as to be almost unsafe and the ladder rungs were rotten. At the ex-Wehrmacht Forst Munster the station was several kilometres distant from any dwelling-house and the telephone had been dismantled some time previously. At Kloster Forst Soltau the station was adjacent to the Revier Förster's house, but it was found that the view to the north had become restricted for the past 6 or 8 years by a fast-growing plantation of trees. In both cases the look-out platform was completely unprotected from the weather. The worst fire season occurs commonly at a period of biting early spring winds with several degrees of frost.

The system of fire warnings is well laid down and only lacks efficiency in so far as telephone communications are inadequate and at the present time bicycles or motor-cycles (or commonly the tyres thereof) are missing. Fire sirens or maroons are unknown in the Regierungs Bezirk.

The Kreis is divided up into three danger zones, each under a Forstmeister who for fire purposes has authority as a Danger District Chief (*Gefahrenbezirksleiter*).

Under each D.D.C. are about 10 Revier Försters having authority as Sub-Danger District Chiefs (*Untergefahrenbezirksleiter*). In normal cases the S.D.D.C. takes full control of the fire-fighting organization, and all formations (fire brigades, police, and civil population) come automatically under his complete control. In large fires the D.D.C. assumes control on arrival, after full reconnaissance.

The S.D.D.C. or a member of his family (normally his wife) must be on call at the Försterei at all hours of the day and night during danger periods, and in his personal absence the given member of his family must be in immediate touch with an appointed substitute. 'Runners' with cycle or motor-cycle are theoretically held standing by at the S.D.D.C. office.

All telephone calls in the event of fire are prefixed by the word *Waldbrand* (wood fire), which ensures high priority, a feature very necessary in a telephone system of only normal 'wait and see' efficiency.

On the outbreak of fire the watchman's immediate duty is to make contact with the local fire brigade and the Burgermeister, and then either direct or via the Burgermeister with the S.D.D.C. The fire brigade has special forest fire-fighting equipment which is rushed to the defined meeting-place. The Burgermeister calls out all available peasants and has power to enforce their attendance, though in normal times everyone volunteered readily. He also warns the police. The local people called out for fire-fighting receive no pay, though at present they get special ration issues on a standard scale. The local fire brigade warns the higher Kreis Fire Brigade Officer who is in direct contact with all other local brigades within the Kreis. Fire brigades are voluntary bodies and at present are inadequately equipped with clothes and footwear. Likewise the S.D.D.C. warns the Danger District Chief and the local police warn the Chief Police Officer of the Kreis. In case of the fire becoming serious further calls are sent out to the Kreis Forstmeister and to the Landrat. The whole chain of responsibility is thus well defined and ensures the collection of all available organized man-power.

In addition to the regular fire brigades there exist at certain of the Revier Försterei or S.D.D.C. depots small mobile fire-fighting units comprising a lorry equipped with beaters, axes, fire-pumps, spare fluid and gas bottles, and manned at danger seasons with stand-by forest workers.

Fire-fighting equipment which is kept in readiness at every regular forest worker's house and in larger numbers at every Försterei and Fire Brigade depot is regularly overhauled and kept in good condition. The standard form of beater for ground fires consists of a 'hand' or fan of spring steel strips mounted on a 10-foot bamboo handle and strikes one as being a very light and effective implement for use in heather, grass, &c. The Germans, however, place great reliance on the use of sapling pine or spruce trees freshly cut and trimmed up at the site of the fire. Though one would prefer a fresh hardwood sapling beater it can but be agreed that fresh fir besoms are undoubtedly better than the old dry and brittle birch besoms not uncommonly found in roadside racks in some of our British forests. The Germans in this district do not maintain any roadside depots of fire beaters or other equipment.

Within recent years the Germans have become greatly impressed with the knapsack type of fire sprayer, using a solution of calcium chloride and sodium acetate (60 kg. of calcium chloride, 10 kg. of sodium acetate per 1,000 litres of water). Huge vats of the prepared solution are maintained at the Försterei ready for filling the knapsack sprayers and renewing the barrels on the fire lorry. The type of sprayer favoured is that designed by Forstmeister Tschaen, in which the metal container holds 20 litres of fluid, enough to last 'full out' for 3 to 5 minutes. The tank has a small metal cylinder of liquid carbon dioxide and a simple system of valves to maintain adequate pressure for the usual duplex spray or direct jet. The gas bottle is adequate for four or five refills of water or solution, and it is claimed that the reduction in temperature caused by the liberation of the gas through the solution gives an added anti-fire effect. The apparatus, which weighs 65 lb. when full, strikes one as being rather heavy for comfortable use and is not too well designed to fit snugly on the back. However, the compressed-gas bottle is a great advance on the hand pump in that the operator has both hands free and has no physical exertion. The operations of refilling with solution and replacement of gas bottles are simple and quick.

The staged demonstration was rather too carefully organized to be quite convincing. In a large felled area immediately adjacent to a main road and only a few minutes' walk from the Revier Förster's depot an accumulation of dry lop and top had been raked together. Three forest workers and a motor-cycle patrol stood by while the fire was kindled. The motor-cyclist dashed away (fortunately without the usual German trouble of a flat tyre!) and the forest workers began to operate their beaters. That the fire lorry and stand-by men were all in readiness at the Försterei we had already seen. In 5 minutes the lorry pulled up on the roadside and the knapsack sprays were in use within a further half a minute. The chloride-acetate solution was certainly effective, though perhaps but little more so under the simple conditions there prevailing than would have been plain water. It is, however, very strongly confirmed that this solution effectively stops the slow smouldering of embers and rotten tree stumps and will even 'seal' the bark of young pine to such an extent that a running ground fire will not injure the trees.

CONCLUSION.

1. In the technique of fire prevention and fire fighting it is apparent that the Germans in the area studied can teach us little. Their greatest safety lies in the forest-mindedness of the population and in the powers of the Burgermeisters to call out all available man-power.

2. The unification of control vested in the Forest Officer, including authority over the fire brigade, police, and general public, is a valuable feature in fire-fighting organization.

3. The present shortcomings in the organization are partly the inevitable aftermaths of war (e.g. shortage of transport, tyres, and telephone communication), but to some extent inertia on the part of the German Forest Service.

4. The compressed-gas knapsack spray using a solution of calcium chloride and sodium acetate is considered to be of great value.

THE EFFECT OF ATMOSPHERIC HUMIDITY ON THE DEVELOPMENT OF FIRES

By J. BRYAN

(Department of Scientific and Industrial Research, Forest Products Research Laboratory)

INTRODUCTION.

IN the issue of *Forestry* for 1946 (vol. xx) H. L. Edlin (1) published some very interesting data on hourly variations in the incidence of forest fires, compiled from observations taken over a period of 16 years on an area of about 78,000 acres in the south of England. These data are the more valuable in view of the paucity of published records on this subject. Consideration of the figures given in the article has led the present author to give an account of some experiments on the effect of atmospheric humidity on the burning of wood carried out at the Forest Products Research Laboratory during the war, and to discuss the results in relation to the data published by Edlin.

It is now generally agreed that ease of burning of wood is considerably influenced by its moisture content. Moisture content of wood is largely controlled by the relative humidity of the surrounding air; and to the extent to which it influences moisture content, relative humidity must influence ease of burning. The moisture content of wood, however, does not come into immediate equilibrium with the relative humidity of the surrounding air and, in fact, may take days or even months, depending mainly on the size and species of the wood. At any one time, therefore, moisture content of the wood and relative humidity of the air may not necessarily be in direct equilibrium relationship, particularly under conditions of rapidly fluctuating relative humidity. On first consideration it would not appear likely that humidity in itself, apart from its effect on moisture content, would have any appreciable effect on burning but, in order to make sure, it was decided to carry out a limited series of tests, a description of which is given below.

EXPERIMENTAL PROCEDURE.

Matched samples, $\frac{3}{8} \times \frac{3}{8} \times 24$ in., of Baltic redwood, Douglas fir, and western red cedar were conditioned to constant weight at relative humidities of 30 per cent., 60 per cent., and 90 per cent., and a temperature of 25° C. Samples conditioned at each humidity were then tested at the three different humidities by means of a strip-burning test, which consisted of suspending the sample vertically and igniting at the lower end with a standardized bunsen-burner flame for a period of one minute. The samples were transferred individually in glass tubes and tested immediately on removal from the tube. The temperature in the testing laboratory was kept constant at 25° C.

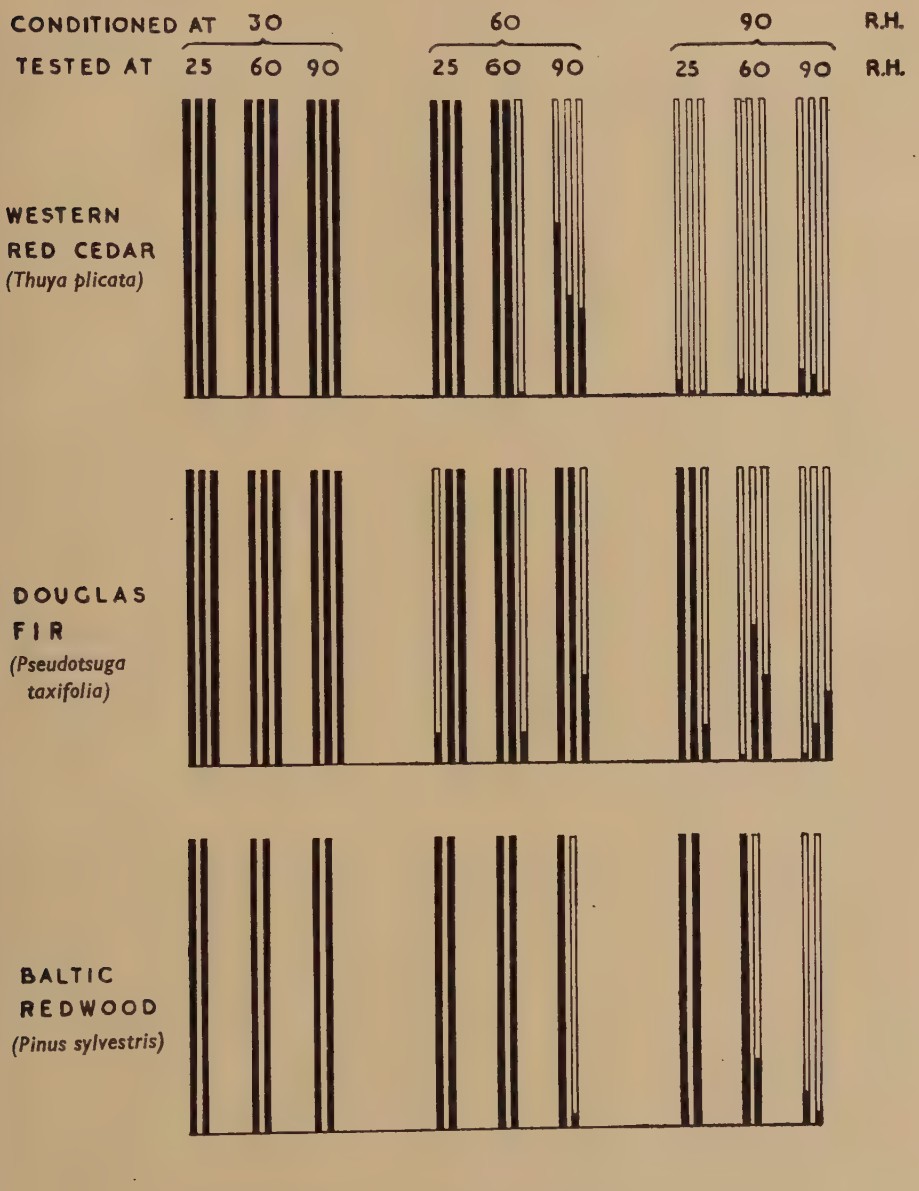

CONDITIONED AT 30 60 90 R.H.
TESTED AT 25 60 90 25 60 90 25 60 90 R.H.
WESTERN RED CEDAR (Thuya plicata)
DOUGLAS FIR (Pseudotsuga taxifolia)
BALTIC REDWOOD (Pinus sylvestris)
DARK PORTION INDICATES EXTENT OF BURNING OF EACH STRIP

FIG. 1. Effect of moisture content and humidity strip-burning test (R.H.=relative humidity)

Table I shows the number of samples out of a total of 3 (2 in the case of Baltic redwood) which burnt out completely after removal of the igniting flame.

TABLE I

Species	*Samples conditioned at R.H. (relative humidity) of*	*Number of samples, out of three tested, which burnt completely (Two samples only tested in the case of Baltic redwood)*		
		Tested under conditions of		
		22–25% R.H.	*60 % R.H.*	*90 % R.H.*
	%			
Western red cedar (*Thuya plicata*)	30	3	3	3
	60	3	2	0
	90	0	0	0
Douglas fir (*Pseudotsuga taxifolia*)	30	3	3	3
	60	2	2	2
	90	2	0	0
Baltic redwood (*Pinus sylvestris*)	30	2	2	2
	60	2	2	1
	90	2	1	0

Fig. 1 shows diagrammatically the length of each test specimen which was burned. This measurement was based on the maximum height up the sample at which flame issued from the wood after removal of the igniting flame.

DISCUSSION OF EXPERIMENTAL RESULTS.

The results of these tests definitely indicate that humidity of the surrounding air has some influence on the burning of wood, irrespective of its effect on the moisture content. The effect is most pronounced where continuity of burning is in the balance, and in such cases air humidity may decide whether flaming will continue or not. In these particular tests the effect is most obvious in the samples conditioned at 60 per cent., whilst it is not apparent in those conditioned at 30 per cent., all of which burnt out. This is because of the particular size of test specimen. No doubt, with thicker samples the effect would be most pronounced on those conditioned at 30 per cent. and would not be so manifest in the higher moisture content ones. The quantitative significance of the humidity effect is difficult to assess, but from these limited tests it would appear to be appreciable and at least as significant as the effect of species, within the range tested. However, under the unstable conditions existing when flaming just may or may not proceed, the effect of any factor influencing burning one way or the other may decide the issue, irrespective of its quantitative effect.

There are several possible explanations as to why humidity affects burning, one being the reduction of oxygen content in air with increased humidity. If this is the explanation, the effect would be related to absolute rather than relative humidity and would be more significant at higher temperatures. Other suggested

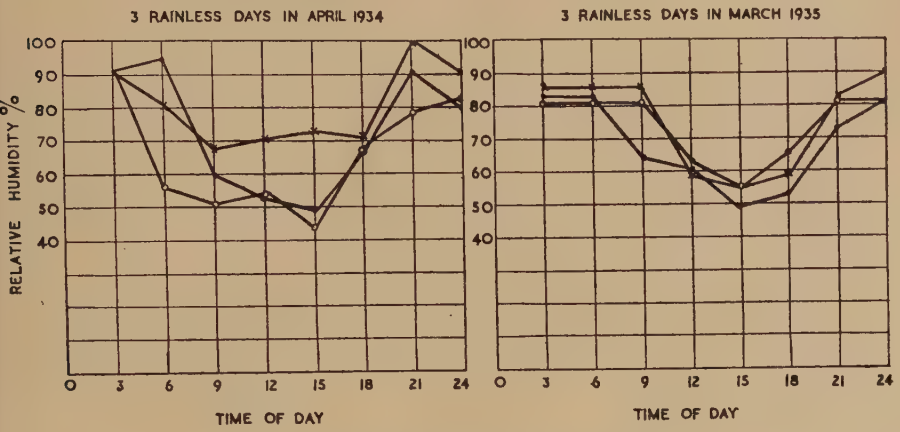


FIG. 2. Three-hourly humidity variation curves

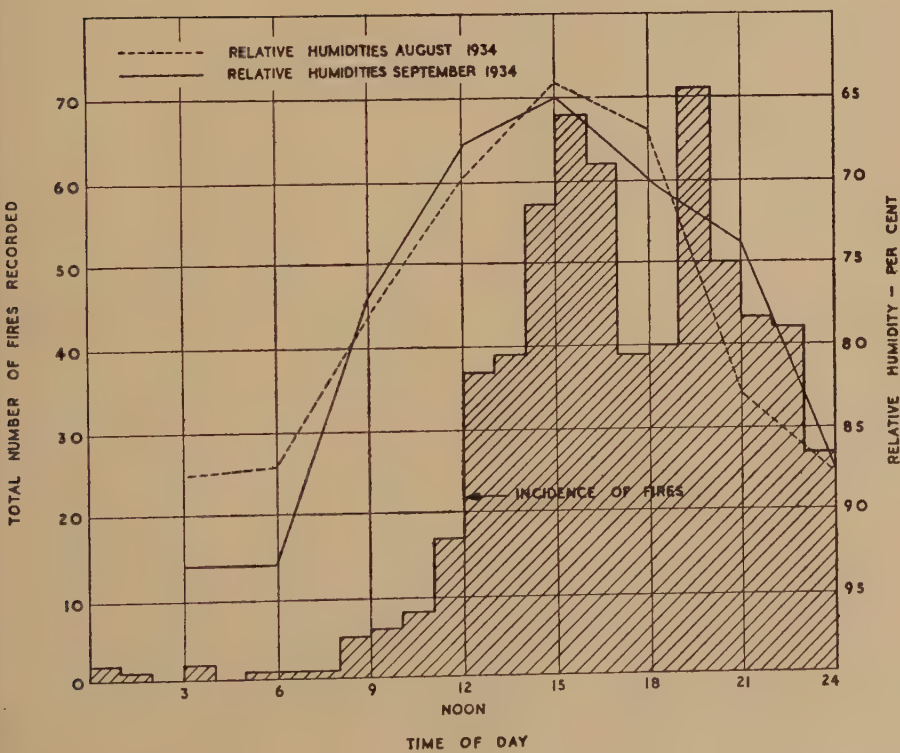

RELATIVE HUMIDITIES AUGUST 1934
RELATIVE HUMIDITIES SEPTEMBER 1934
INCIDENCE OF FIRES
TOTAL NUMBER OF FIRES RECORDED
RELATIVE HUMIDITY — PER CENT
0 10 20 30 40 50 60 70
65 70 75 80 85 90 95
3 6 9 12 15 18 21 24
NOON
TIME OF DAY

FIG. 3

explanations are possible variation in the conductivity of the air and possible influence of moisture vapour on the physical characteristics of the flame.

EFFECT OF ATMOSPHERIC HUMIDITY IN RELATION TO INCIDENCE OF FOREST FIRES.

It is reasonable to assume that the results obtained with the thin wood samples will be applicable to material in which fires first develop in heathlands and plantations. Also when a source of ignition is present the material factor is whether or not a fire will continue to burn. Under adverse conditions a thousand matches may be thrown down without causing a fire, whereas under favourable conditions a single match may result in a conflagration. Such records of humidities as are available indicate that on the average rainless day the humidity is highest in the evening, begins to fall about 6 a.m., reaches a minimum at about 3 p.m., and rises to a maximum again at 9 p.m. Fig. 2 shows graphs obtained from recordings of humidity at Princes Risborough. In Fig. 3, graphs of this average hourly variation in humidity for the months of August and September 1934 have been superimposed on a reproduction of Edlin's chart for the hourly incidence of 619 fires in the New Forest between 1926 and 1942 (1). The data are not strictly comparable, but the general correlation is fairly obvious and would be closer still if the fire-incidence chart had been corrected for summer time and double summer time, which would have reduced in the chart the incidence of fires in the late evening. The peak rise in the incidence of fires between the hours of 7 and 8 p.m. is not reflected in the humidity graph and is not explainable on these grounds.

The incidence and development of fires are no doubt influenced by the two factors of human activity and weather conditions, and it is difficult to assess the relative effect of each. They are indeed complementary and it is the simultaneous combination of the two which results in fires. Human activity has no consequence when conditions are unsuitable for fire spread. It would appear, therefore, that weather conditions, and particularly atmospheric humidity, are overriding factors. Consequently alertness against fire should be governed preferably by the hygrometer rather than by the clock.

LITERATURE REFERENCE.

(1) Edlin, H. L.: 'Hourly Variations in the Incidence of Forest Fires'. *Forestry*, xx. 26–9, 1946.

SCOTS PINE REGENERATION IN A NEW FOREST INCLOSURE

(*Pinus sylvestris* L.)

By E. W. JONES

(*Department of Forestry, University of Oxford*)

INTRODUCTION. THE SITE.

FROM 1939 to 1941 many of the Scots pine crops of the New Forest were felled, leaving seed-bearers for natural regeneration by the shelterwood-compartment system. One of these areas, in Busketts Lawn Inclosure, has been studied by the members of the Imperial Forestry Institute, Oxford, since the beginning of regeneration. Now, after 5 years, it is possible to feel confident that the greater part of the area has been regenerated satisfactorily, and to draw some general conclusions on the causes of success or failure. Some observations relating to Douglas fir regeneration and to cone-production of Scots pine in this area have already been published [Jones, 1943 and 1945 (2, 3)]; and the 1945 paper contains a fuller description of the site than can be given here.

Bartley Water flows through Busketts Lawn Inclosure from west to east, at the bottom of a deeply incised and very meandering channel. Prior to enclosure in 1864 there was 'a long strip of wood on each side of the Bartley Water full of good oak and beech' [Richardson, 1787 (4)] (Fig. 1). Most of this strip was subsequently planted with Douglas fir, but in 1941 what was doubtless its outer margin had in places a mixed crop of pine and oak, with a high proportion of oak. North of this, over most of the site of the present Compartment 8 (Fig. 2) and all of C. 3 was Busketts Lawn; 'a very large open lawn, the West end of which is rather rough and coarse, but is good timber land. The East end is good pasture' [1787 (4)]; while to the south, covering most of the present Compartment 9 and all of C. 14 was Old Lodge Lawn, 'wet in winter, but if drained would make fine timber land', according to the 1787 surveyors. The former lawns bore pure Scots pine in 1941. It is not certain, however, whether they were planted as pure crops or as mixtures of pine and oak, but the presence of local patches of oak in Compt. 3 suggests that they were planted as mixtures. If this is the case, then the survival of oak on the old woodland sites near the stream and its disappearance elsewhere must be ascribed to soil differences. It is possible, of course, that the oak was not planted but came from advance growth and from seed present in the ground on the old woodland sites.

There is considerable variation in soil over the Inclosure. On the strip of former woodland are brown forest soils; deep, well-drained loams close to the stream and gleyed heavy loams and clays a little farther away. Farther from the stream, beyond the brown forest soils under the former lawns, are gleyed podsols. There is also a sharp contrast in vegetation between the two regions. On the brown forest soil, beneath the oak–pine crop, was a mull humus with pre-

dominantly broad-leaved litter. *Rubus fruticosus* was often abundant, and herbs such as *Oxalis acetosella*, *Lysimachia nemorum*, *Luzula pilosa*, and *Primula vulgaris* abundant. Since felling, *Teucrium scorodonia*, *Anthoxanthum odoratum*, and *Deschampsia flexuosa* have increased in abundance and are very characteristic of this region. Over the rest of the Inclosure are two main dominants, *Molinia coerulea*, the 'flying bent' or 'purple moor grass', and *Pteridium aquilinum*, the bracken. In general there is an irregular belt where bracken is dominant on either

Fig. 1. The Busketts Lawn district in 1787, from the survey by Richardson, King, Driver, and Abraham (4).

side of the brown-earth strip, while farther away *Molinia* is dominant. There are, however, patches of bracken elsewhere, notably a belt near the north of Compt. 3, on ground which is rising slightly from the valley floor towards the high ground north of the Inclosure.

The gleyed podsol profiles show great variation in distribution of gleying, degradation, humic horizons, horizons of flints, &c., amongst which it is difficult to pick out consistent variation with vegetation. The soil character showing the closest connexion with vegetation appears to be the colouring of the horizon from a depth of about 8 to 16 in. In *Pteridium* areas, yellows and browns predominate in this region: in the *Molinia* areas, blues and blue-greys. The *Molinia*

area of Compt. 14 appears to be characterized by the dirty blue colouring, with ill-defined sparse mottling above, to within a few inches of the surface. An A horizon and a humus pan are present in some places. Beneath *Pteridium*, mottling may come nearly to the surface, but the mottling is ill defined and yellow colour predominates. Probably the level at which well-defined blue and orange gleying begins is lower under *Pteridium* than under *Molinia*. *Pteridium* is frequently associated with higher ground, but changes in level of a few inches are obviously important in determining the vegetation type.

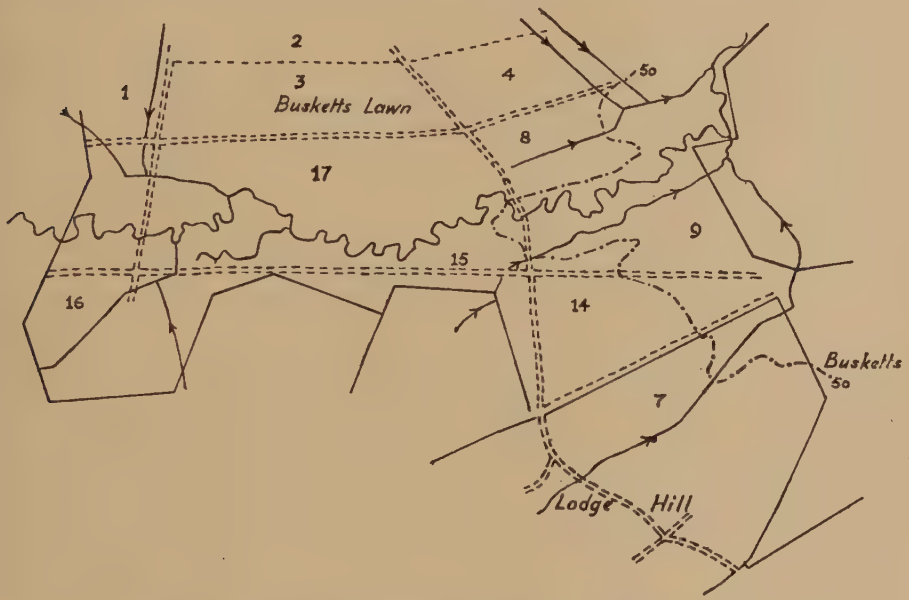


FIG. 2. Map of part of Busketts Lawn and Lodgehill Inclosures.

Soils bearing *Pteridium* are certainly not necessarily any drier than those bearing *Molinia*. Indeed, in April 1947 Mr. J. Holownia found that in the valley floor there was a considerably higher water-table beneath *Pteridium* than beneath *Molinia* (1). In September 1941 the water-table was at a depth of about 7 ft. The essential difference between the soil of the two kinds of vegetation seems more likely to be one of aeration than of wetness.

PROGRESS OF WORK AND METHODS OF STUDY.

The first fellings were made in Compt. 3 in the winter of 1940–1. Strips 100 ft. wide were clear felled, alternating with strips 60 ft. wide which were left intact. Shelterwood fellings, leaving about 20 to 25 trees per acre, were made in the pine crops of Compts. 9 and 14 during the winter of 1940–1, while the shelterwood fellings over the pine of Compt. 8 were carried out during the summer of 1941 and the following winter. During the winter of 1941–2, in Compts. 3, 4, 8, and 17 the Douglas fir was heavily thinned, and most of the oak was felled during the summer of 1942. Members of the Imperial Forestry Institute, Oxford, first visited the area in June 1941, when work was concentrated

on the Douglas fir regeneration. A. Foggie, however, made some records of the amount of regeneration in Compt. 3. In September 1941 a sample plot in the pine of Compt. 8—then being felled—was studied, and a few records were obtained of the condition in Compt. 9. In June 1942 a full assessment was made of regeneration in Compts. 8, 9, and 14, and this was repeated in June 1943. The observations made in June 1944 were directed towards solving specific problems, particularly the effect of bracken on regeneration. In 1945 the area was visited, but only superficial observations were made. A final assessment was made in July 1946. For the main assessments quadrats 2 ft. by 2 ft. were employed. They were spaced at approximately equal distances (measured by pacing) on transects crossing the compartments at right angles to the general course of the stream. The transects themselves were spaced at equal-paced intervals. The information recorded varied slightly from year to year, but in general there were recorded for each quadrat:

number of 1st-year, 2nd-year, and older Scots pine seedlings;
number of 1st-year, 2nd-year, and older Douglas fir seedlings;
number of seedlings of other species.

Percentage cover of *Pteridium*, *Rubus fruticosus*, *Molinia*, other grasses, herbs (including not only true herbs but also *Calluna*, *Lonicera*, coppice shoots of oak, birch, &c.), moss, litter, and bare ground. The percentages totalled 100 *without Pteridium*.

Foggie, in his assessments in Compt. 3, recorded 1st-year seedlings and two classes of older seedlings, the smaller ones approximately 2 to 3 years old and the larger ones 4 years old or more. Vegetation cover was recorded in 1943 and 1944, but not in 1941 or 1942. The assessment was made along a single transect sample strip, 1 ft. wide, by contiguous quadrats 3 ft. by 1 ft. The lengths were measured in 1943 and 1944 but estimated in 1941 and 1942. Thus the quadrats used here were 3 sq. ft. as compared with 4 sq. ft. in other areas, but in presenting the data no adjustment has been made for this difference in size.

It is unfortunately very difficult to treat these assessments statistically and assign any values to the probable limits of error. The quadrats were not spaced truly at random, but in the present circumstances this is probably a minor consideration. The seedlings are not distributed at random (cf. p. 158) but tend to be aggregated into groups, and variances are commonly 3 to 4 times those which would be obtained with random (Poisson) distributions. This will make the sampling error correspondingly high and will also invalidate the use of the customary tests of significance. On the other hand, even if the customary tests were applicable, the sampling error would be considerably less than that indicated by the total variance of the number of plants per quadrat, a considerable part of which is accounted for by gradations in stocking from place to place. The eastern part of Compt. 8, for example, is more poorly stocked than the western part. The fact that each year the transects were distributed over the whole area will have eliminated much of this source of variability from the sampling error. The statistical procedure appropriate to stratified random samples would thus

be more applicable than that appropriate to fully randomized samples. In 1943 a duplicate assessment was made in Compts. 9 and 14, recording only vegetation type and presence or absence of seedlings, 341 quadrats distributed over 7 transects being examined. This sampling was thus considerably more intense than that of the main assessment of the same area in which 194 quadrats distributed over 4 transects were employed. The two assessments are compared in the following table.

TABLE I. *Comparison of duplicate assessments of Compartments 9 and 14 in 1943. Total number of quadrats and percentages of total number stocked with seedlings*

	Pteridium areas		*Molinia areas*		*Other types*		*All areas*	
	Number of quadrats	*Percentage stocked*	*Number of quadrats*	*Percentage stocked*	*Number of quadrats*	*Percentage stocked*	*Number of quadrats*	*Percentage stocked*
Main assessment	72	29·2	96	59·4	26	3·85	194	40·6
Second assessment	105	30·6	187	64·7	49	14·3	341	47·0

These figures suggest that discrepancies between the estimates of the major totals at least should not exceed about 10 per cent.

There are three aspects in regeneration which we shall consider:

(*a*) the seed supply;
(*b*) the seed-bed conditions influencing germination and establishment of the young seedlings;
(*c*) the survival during the first few years until the seedlings are out of danger from suppression by competing vegetation.

(*a*) *The seed supply.*

Scots pine cones ripen in the autumn and the seed is liberated from the cones during the following spring and early summer. There had been a good crop of cones in 1940, and in 1941 1st-year seedlings were abundant over the whole area. Assessments of cone-production were made during some of the following years. By the beginning of July the cones are nearly full size and are bright green, so that they are very easily seen, and by examining the crowns with binoculars an estimate of their density can be made. By the end of July the colour has darkened and they are much more difficult to pick out. By the end of August they are brown, and it is then impossible to separate them from the older cones. Empty cones remain on the tree for a variable period of years, so that from them it is only possible to estimate the average heaviness of previous crops over a period of several years.

The figures in Table II illustrate the fact that after a shelterwood felling there is a serious, though apparently temporary, fall in cone production. The numbers of cones borne by the seed bearers in Compts. 8 and 9 are low compared with those in the strips in Compt. 3. The cones ripening in autumn 1942 were pollinated, of course, in the spring of 1941, before the seeding felling in Compt. 8.

These trees, it must be remembered, had already borne heavily the previous year. By 1946 it would appear that crops were beginning to increase again.

TABLE II

	Compartment 8				*Compartment 9*				*Compartment 14*				*Compartment 3*			
	1	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*
1942 old cones	55	30	15	20	..	..	..	..	..	..	..	..	..	..	..	..
1942 young cones . .	60	25	15	20	..	..	..	..	..	..	..	..	..	..	..	..
1943 . .	30	30	40	30	35	35	20	20	37	38	25	40	54	32	10	50
1946 . .	38	46	16	50	54	28	18	50	..	..	..	..	62	24	14	50

1 = Percentage of trees with abundant or frequent cones.

2 = Percentage of trees with occasional cones (less than about ¼ of the branch-apices bearing cones).

3 = Percentage of trees with no cones.

4 = Number of trees in sample.

This picture is confirmed by the figures for the number of 1st-year seedlings present (Table III). Here, of course, the fall in numbers from 1941 to 1944 might have been due to the ground cover closing and making conditions unsuitable for establishment, but the rise in 1944–6 can only be due to increased seed

TABLE III

		Total number of quadrats in sample	*Percentage of quadrats with 1st-year seedlings*	*Mean number of 1st-year seedlings per quadrat*	*Mean number of 1st-year seedlings per occupied quadrat*
Compt. 8	1941	104	51·0	18·0	2·5
	1942	244	8·2	0·091	1·1
	1943	138	1·45	0·0145	1·0
	1944	100	2·0	0·02	2·1
	1946	100	7·0	0·11	1·6
Compts. 9 and 14	1941	46	9·5	..	..
	1942	211	9·5	0·137	1·45
	1943	167	4·2	0·060	1·43
	1944	473	2·75	0·0275	1·0
	1946	145	34·5	0·973	3·02
Compt. 17	1941	..	..	0·167	..
	1942	..	2·6	0·068	2·6
	1943	..	1·3	0·019	1·5

supply. It will be noticed that this rise is far more pronounced in Compts. 9 and 14 than in 8. This might be explained by the fact that the general ground cover is much denser and more continuous in 8 than in 9 and 14; but the impression was gained while making assessments in 1946 that even in favourable places where there was still much bare humus and conifer litter, seedlings were

much less abundant in 8 than in 9 and 14. A series of samples in sites of this kind showed that this was, in fact, the case (see Table IV). A poorer seed supply due to the small-crowned trees left as seed-bearers [cf. Jones, 1943 (2)] seems to be the only likely explanation of this difference between the two blocks; and the fact that the number of seedlings in such favourable spots is higher close to either margin, where there is a seed supply from adjacent unfelled stands, is in agreement with this suggestion.

TABLE IV. *Number of quadrats with seedlings, and number of seedlings, in random samples each of 10 quadrats in sites with bare litter, July 1946*

		1st-year number of		*2nd-year number of*		*3rd-year number of*	
		Quadrats	*Seedlings*	*Quadrats*	*Seedlings*	*Quadrats*	*Seedlings*
Compt. 8	Centre (1st sample)	5	9	3	5	1	2
„	Centre (2nd sample)	5	7	7	10	3	7
„	Western margin	7	22	7	32	4	4
„	Eastern margin	9	19	7	19	2	2
Compt. 9	Western margin	10	48	7	28	3	4
„	Centre	10	68	8	28	1	1
Compt. 14	Centre	10	58	8	18	7	15

For comparison of number of 1st-year seedlings in 40 quadrats in Compt. 8 with those in 30 quadrats in Compts. 9 and 14, $\chi^2_{[5]} = 22{\cdot}6$, and the probability of chance occurrence of this difference is less than 0·001.

For comparison of number of 2nd-year seedlings in 20 quadrats in centre of Compt. 8 with those in 20 quadrats near margins, $\chi^2_{[2]} = 7{\cdot}7$, and the probability of chance occurrence of this difference is nearly 0·02.

A further careful comparison of cone-production in the two areas showed that the difference was attributable to the much higher proportion in Compts. 9 and 14 than in 8 of seed-bearers which could be classified as former dominants (55 per cent. and 37 per cent. respectively) rather than to differences in cone-production by trees of the same class. However, the decrease in number of 1st-year seedlings after 1941 is not due solely to changes in cone-production caused by isolation of seed trees, since it is equally pronounced in the unfelled strips of Compt. 3 and the intact crops of Compt. 17.

(b) The seed-bed conditions influencing germination and establishment of the young seedlings.

The time of felling is an important factor in the success of regeneration. The figures in Tables X and XI (lower section, pine, any age) show that there are big differences between the density of the seedling population in the various

compartments. Irrespective of vegetation, 8 is the most poorly stocked and 3 the best. There is no doubt that these major differences in stocking are due to the time of felling. In all these areas the bulk of the seedlings come from the crop which germinated in 1941 (cf. the numbers of quadrats with 1st-year seedlings in 1941). In Compt. 8 felling was going on throughout the autumn of 1941 and most of the seedlings there were destroyed. Moreover, the seedlings had come up much more thickly on the felled area than beneath the unopened canopy (cf. 8, 9, and 14, 1941), a fact also shown by A. Foggie's figures in Compt. 3. In Compts. 3, 9, and 14 the felling was completed in time for the establishment of seedlings, but operations had been completed rather earlier in 3 than in 9 and 14, so that in Compt. 3 the places where lop and top had been burned bore a luxuriant crop of seedlings in 1941, whereas in 9 and 14 they were without seedlings.

Scots pine seed falls from the cones during the spring months, and under natural conditions germinates over a long period during late spring and early summer. The difference between the numbers of 1st-year seedlings in 1941 in Compt. 9 (91 per cent. stocked in September) and 3 (64·5 per cent. stocked in July) probably indicated that germination was not completed by July. In the same way the number of 2nd-year seedlings recorded was frequently slightly higher than the number of 1st-year seedlings recorded the previous July; the rise is slight and perhaps not significant, but may be due to the same cause.

The conditions needed for germination of seed and early growth of seedlings may be studied in relation to the micro-environment or in relation to the major ground-cover conditions. The two aspects are interrelated, for the degree to which a given ground-cover is favourable will depend presumably to a large extent on the frequency with which it presents favourable loci for germination.

If seed germinated wherever, or almost wherever, it fell, conditions being equally favourable throughout the site, the distribution of 1st-year seedlings would be random, and the frequency with which quadrats containing various numbers of seedlings occurred would form a Poisson distribution. In fact there are almost always significant departures from a Poisson distribution (cf. Table V). There are always too few quadrats with low numbers of seedlings and too many with numerous seedlings, thus suggesting that there are favourable spots where seedlings are especially abundant. This holds within a single ground-cover type as well as for the area as a whole. Only when 1st-year seedlings are very scarce, as in Compt. 8, is the distribution sufficiently near random to be treated as such. When quadrats with the larger numbers of seedlings are excluded from consideration (Table V, columns 2 and 3), the remaining population shows a much closer approach to a random distribution, though there is still some suggestion of agglomeration of seedlings in favourable spots, even when quadrats with as few as 4 seedlings are considered. From the silvicultural point of view, as well as for any evidence it may give on their nature, it is interesting to know whether these 'favourable spots' are distributed at random or not. For this purpose the data were divided into groups of 4 consecutive quadrats. If in the entire population of x quadrats there are w quadrats with 4 or more seedlings, the

TABLE V. *Mean number of seedlings per quadrat and its relative variance (V/M)*

		All quadrats		Quadrats with not more than 6 seedlings		Quadrats with not more than 3 seedlings	
		Mean	V/M	Mean	V/M	Mean	V/M
1943	*Molinia*, Compt. 8	0·6125	4·18	0·398	1·59	0·303	0·970
	Molinia, Compts. 9 and 14	1·79 $\chi^2_{[8]} = 49$	3·08 $p = <0{\cdot}001$	1·25 ..	1·56 ..	1·06 $\chi^2_{[1]} = 27{\cdot}1$	1·34 $p = <0{\cdot}001$
	Pteridium, Compt. 8	0·432	4·4	0·280	2·1	..	..
	Pteridium, Compts. 9 and 14	0·888 $\chi^2_{[2]} = 30{\cdot}26$	3·9 $p = <0{\cdot}001$	0·536 ..	2·74 ..	0·277 $\chi^2_{[1]} = 1{\cdot}15$	1·30 $p = <0{\cdot}25$
1942	*Molinia*, Compt. 8	0·355	3·9	..	..	0·1494 $\chi^2_{[1]} = 30$	1·54 $p = <0{\cdot}001$
	Molinia, Compts. 9 and 14	1·70	4·0	..	..	..	1·36

The relative variance (V/M) is the variance divided by the mean. For a Poisson distribution this is, within the limits of sampling errors, unity. Values greater than unity indicate aggregation of seedlings.

The values of χ^2 and the corresponding probabilities in this table measure the departure of the observed distribution from the theoretical Poisson distribution with the same mean, and the probability of getting this departure by chance in sampling.

probability of any one quadrat being of this kind is w/x, and, from the binomial, the probability of n quadrats in any group of 4 being of this kind is

$$\frac{4!}{n!(4-n)!}\left(\frac{w}{x}\right)^n\left(\frac{1-w}{x}\right)^{(4-n)}.$$

In this way the probability of any group of 4 quadrats containing 0, 1, 2, 3, or 4 such quadrats was calculated; and these expected frequencies were compared with those actually found. This has been done with the figures for two years (1942 and 1943, Table VI). In 1943 the distribution of these better-stocked patches conformed remarkably closely to the random. In 1942 there was a rather greater divergence, but one which might occur by chance seven times in a hundred. There are insufficient figures to justify this procedure with the *Pteridium* areas, but in the *Molinia* areas in 1942 and 1943 the agreement between the theoretical random distribution and the actual distribution was good.

The general picture, then, would seem to be that of a sparse population generally and randomly distributed, together with limited areas, themselves distributed at random, which are more favourable and carry a seedling population of far higher density.

The search for the favourable ground conditions may be continued by an examination of the figures for percentage covers by a method explained in an earlier paper [Jones, 1945, p. 55 (3)]. The frequency distribution of quadrats

TABLE VI. *Numbers of quadrats containing more than 4 seedlings per group of 4 consecutive quadrats*

Number of quadrats per group with 4 or more seedlings	*Number of groups: Molinia type*					
	1942, Compts. 9 and 14		*1943, Compts. 9 and 14*		*1943, Compt. 8*	
	Actual	*Expected*	*Actual*	*Expected*	*Actual*	*Expected*
0	20	16·5	11·5	11·33	15	15·3
1	6	10·5	8·0	7·0	4	3·4
2	2	2·77	0·0	1·5	0	0·283
3	2	0·246	1·0	0·17	0	0·0105
4	0	0·0	0·0	0·00	0	0·00
	30		20·5		19	
	$\chi^2 = 1{\cdot}65$		$\chi^2 = 0{\cdot}4165$			
	$P = c.\ 0{\cdot}2$		$P = 0{\cdot}5$			

containing 0–10, 11–20, . . . 91–100 per cent. cover of any desired cover-component (e.g. moss or moss plus litter) with pine seedlings present is compared with the corresponding distribution for the entire population of quadrats or for those quadrats without seedlings. Any favourable condition will be shown by an excess of quadrats possessing it in the one distribution, and in order to test the significance of any such divergencies the χ^2 test may be applied. Some of these frequency curves are shown in Fig. 3 and the deductions which they suggest are tabulated (Table VII). Unfortunately the number of 1st-year

TABLE VII

	Favourable conditions	*Unfavourable conditions*	*Probability of chance occurrence of association*
Pteridium . . .	20–50% cover	Absence, and 50–100% cover	0·05
Molinia coerulea . .	..	..	0·42
Rubus fruticosus . .	5–10% cover	Absence, and 20–100% cover	0·01
Grass (other than *Molinia*)	..	..	0·5
Herbs	Absent	..	0·076
Moss	30–50% cover	50–100% cover	0·41
Litter	80–100% cover	Less than 30% cover	0·18
Bare	80–100% cover	Absent	0·0015
Litter and Bare and Moss .	60–100% cover	Less than 50% cover	0·0012

seedlings in the years for which assessments are available have been small; only in 1942 were there sufficient numbers to use the figures in this way, and even here the figures for Compts. 8, 9, and 14 had to be grouped together. Conclusions can be checked to some extent by the relationship between older seedlings and ground cover, though changes in vegetation and death of seedlings may alter the situation from one year to the next. Caution must be used, of course, in interpreting the indications given by this procedure, for an association between

seedlings and some ground factor, even though statistically significant, does not necessarily imply any causal relationship.

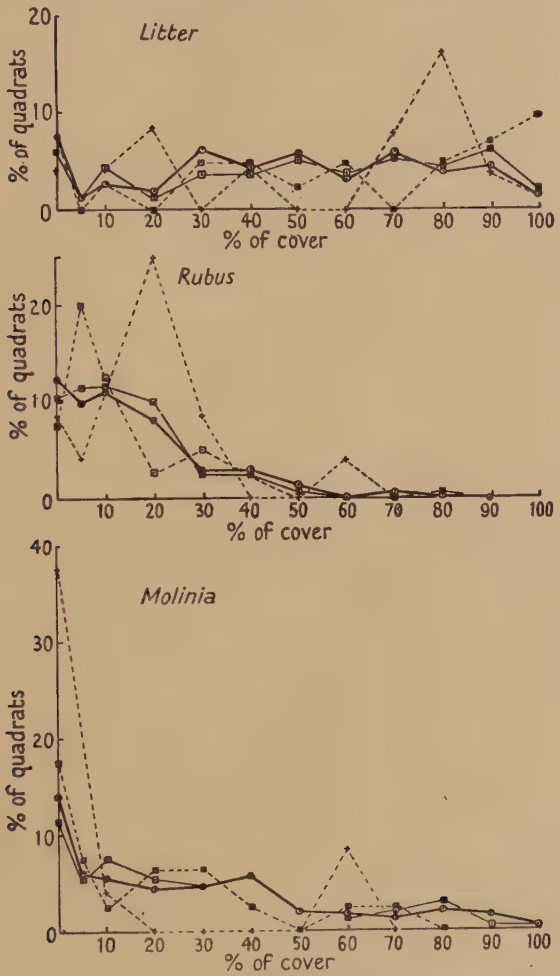


FIG. 3. Relationship between ground cover and presence of seedlings, Compts. 9 and 14, 1942.

The curves show the percentage of quadrats with 0, 5, 10, . . . 100 per cent. cover of litter, *Rubus* and *Molinia*,

(*a*) for all quadrats (——⊙——),
(*b*) for quadrats containing 1st-year pine seedlings (- - -⊡- - -),
(*c*) for quadrats containing older pine seedlings ——⊡——), and
(*d*) for quadrats containing 1st-year Douglas fir seedlings (- - -+- - -).

By far the closest relationship is that between 'bare' ground and seedlings. No other factor or group of factors shows so close a correlation with the presence of seedlings. High litter cover is also favourable. The figure for χ^2 is surprisingly low, but in view of the close connexion between the occurrence of 2nd-year

seedlings and litter the relationship must be considered a genuine one. There is a curious suggestion in several instances that both high cover and complete absence are correlated with absence of regeneration. *Pteridium* and *Rubus* offer the most striking examples of this, though 'herb' cover may perhaps show the same behaviour; it is evident with Douglas fir seedlings as well as with pine seedlings, and in the unfelled crop of Compt. 17, the data for which are not being presented in this paper, as well as in the felled Compts. 8, 9, and 14. In view of the repeated occurrence of the phenomenon it can hardly be accidental, but it is difficult to suggest an explanation which covers all conditions. It seems most likely to indicate a moisture relationship; either that some shelter or shade from open vegetation is a favourable factor, or else that a locally higher soil moisture favours both germination and the occurrence of ground cover.

TABLE VIII. *Mean percentage cover per square foot in quadrats with 1st-year pine, 1946*

Number of 1st-year pine per sq. foot	*Mean percentage cover by*				
	Molinia and Rubus	*Moss*	*Litter*	*Litter+Bare+Humus*	*Litter+Bare+Humus+Moss*
1	25·0	1·2	26·8	31·7	65·5
2	25·0	10·0	32·7	49·1	45·8
3	32·7	13·0	32·0	47·0	53·6
4	21·1	14·3	16·0	68·6	70·0
5 and over	15·6	12·9	52·9	62·9	66·25

Four years later, in 1946, it was again apparent that places where seedlings were entering were characterized by low phanerogamic cover and high cover of litter, moss, or bare ground, usually more than 25 per cent. The relationship is illustrated in Table VIII and Fig. 4. There were only two quadrats with 1st-year seedlings and complete phanerogam cover; one of these had, in fact, 80 per cent. cover of open *Calluna*, beneath which was bare litter; the other represented the rare occasion when a 1st-year seedling does occur in dense vegetation. There were four quadrats with a 2nd-year seedling and complete phanerogam cover, and in all these the vegetation was of the more open type (*Calluna*, *Erica tetralix*, &c.). In all these six quadrats there was only a single seedling. First-year seedlings were never found beneath *Rubus fruticosus* or *Ulex europaeus*, amongst dense *Pteridium* with a thick litter of dead fronds beneath it, amongst luxuriant *Molinia*, nor where there was a thick mat of dead *Agrostis tenuis* or other grass. They were found beneath *Pteridium* when the litter was thin, and also in the larger spaces between *Molinia* tussocks when there was not a thick accumulation of dead leaves. They occurred in carpets of the dwarfer upright-growing mosses (especially *Campylopus pyriformis* Brid. and *Dicranum scoparium* Hedw.) and of lichens, such as *Cladonia silvatica* Hoffm., *C. uncialis* Web., and *C. furcata* Schrad., often growing in cracks in the crusts of these species. *Polytrichum formosum* Hedw., stronger growing but of upright

habit, was perhaps rather less favourable, but many seedlings were found in it. On the other hand, seedlings did not occur amongst robust mat-forming mosses of prostrate habit, such as *Hypnum cupressiforme* var. *ericetorum* B. and S. and *Brachythecium purum* Dixon. They were found on ground which was lightly grown over with *thin* dwarf grasses (*Agrostis* spp., *Anthoxanthum*), *Galium saxatile*, or other dwarf herbs.

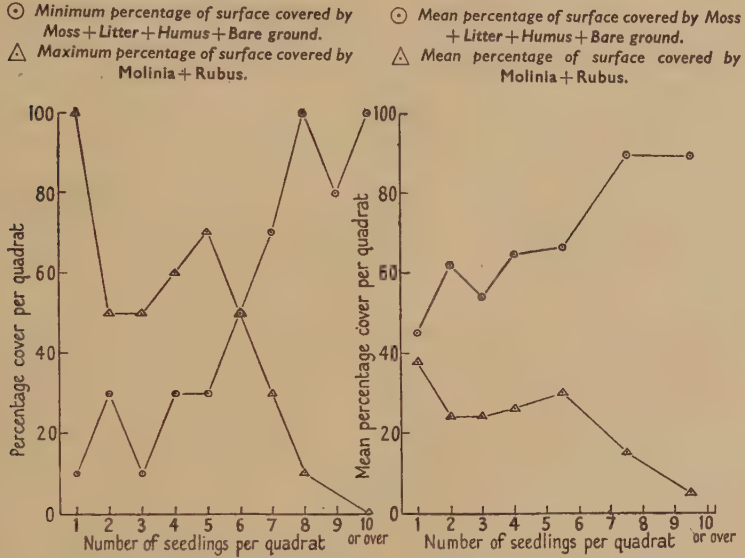

⊙ Minimum percentage of surface covered by Moss + Litter + Humus + Bare ground.
△ Maximum percentage of surface covered by Molinia + Rubus.
⊙ Mean percentage of surface covered by Moss + Litter + Humus + Bare ground.
△ Mean percentage of surface covered by Molinia + Rubus.
Percentage cover per quadrat
Mean percentage cover per quadrat
0
20
40
60
80
100
1 2 3 4 5 6 7 8 9 10 or over
Number of seedlings per quadrat

Fig. 4. Relation between abundance of seedlings and ground cover. Compartments 8, 9, and 14, July 1946.

It is thus clear that the 'niche' suitable for germination and early growth must present some mineral soil, compact litter or humus or a thin carpet of moss, and must not be heavily overgrown by phanerogams. The frequency with which these conditions are presented varies greatly with the vegetation.

(*c*) *The survival during the first few years until the seedlings are out of danger from suppression by competing vegetation.*

Successful regeneration depends on the establishment of the seedlings, and this in its turn largely on the competing vegetation. It is interesting to compare the figures for 1942 and 1943, to see what changes in vegetation they reveal. It must be remembered that in Compt. 8 these years represent the 1st and 2nd seasons after felling, while in Compts. 9 and 14 they represent the 2nd and 3rd years after felling. However, this does not account for all the differences in vegetation between the two compartments. The principal changes are summarized in Tables IX and X. They are, of course, changes of increasing vascular plant cover. In the period of 2 to 3 seasons the *number* of quadrats with *no* litter has not greatly increased (the *decrease* in Compt. 8 must be attributed to sampling error), but there has been a very considerable decrease in the *size* of litter patches.

'Moss' and 'Herbs' (the latter including species such as *Lonicera*, coppice regrowth of *Quercus*, &c., as well as true herbs such as *Galium saxatile*, *Potentilla sterilis*, *Digitalis*, &c.) have spread greatly and show by far the biggest cover changes. It is principally the number of small patches that has increased. The species records (Table X) show that the 'herb' cover increase must be largely due to *Erica tetralix*, *Lonicera periclymenum*, *Galium saxatile*, and to seedling and coppice growth of woody species. Some 10 species additional to those included in Table X showed small and insignificant increases. No decreases of vascular plants were recorded. Ultimately, of course, these subsidiary species would decrease, to be replaced by dominants such as *Pteridium*, *Molinia*, and *Calluna*, unless the growth of pine and other woody species intervened earlier. But the figures show that the subsidiary species are relatively slow-moving. There was still uncolonized litter present in 1946.

It will be noted (Table IX) that the changes between 1942 and 1943 were always greater in Compt. 8 than in Compts. 9 and 14. It is to be expected that the changes in the 1st season of recolonization after felling would be greater than those in the 2nd season. But by 1946 it was obvious that the vegetation cover was far more continuous in 8 than in 9 and 14, so that the greater change in 8 may be due at least as much to site differences as to the time differences.

TABLE IX. *Principal changes in ground cover between 1942 and 1943 as shown by the percentage of quadrats with 0, 5–45, and 50–100 per cent. cover by Pteridium, Molinia, &c.*

Cover	*Compartment 8*			*Compartments 9 and 14*		
	0	*5–49*	*50–100*	*0*	*5–49*	*50–100*
	%	%	%	%	%	%
Pteridium, 1942	76·2	16·5	7·2	62·0	21·0	17·0
Change between 1942 and 1943	−13·8	+3·8	+10·1	−2·8	+1·2	+1·6
Molinia, 1942	34·4	58·0	7·6	27·9	53·3	18·9
Change between 1942 and 1943	−13·4	+2·2	+11·3	−6·3	−1·7	+8·1
Rubus, 1942	29·6	67·3	4·0	25·0	69·1	6·0
Change between 1942 and 1943	−13·6	+2·3	+11·1	−8·2	−0·7	+8·9
Grass, 1942	95·6	4·0	0·4	83·3	15·5	1·2
Change between 1942 and 1943	−7·1	+6·7	+0·3	+4·7	−4·7	0·0
Herbs, 1942	94·0	4·8	1·6	72·0	26·8	1·2
Change between 1942 and 1943	−46·7	+46·5	−0·2	−34·8	+33·2	+2·6
Litter, 1942	23·0	37·2	39·8	15·6	31·9	46·3
Change between 1942 and 1943	−4·9	+25·2	−20·3	+12·6	+20·3	−26·5
Moss, 1942	67·1	28·1	4·8	81·0	16·8	2·0
Change between 1942 and 1943	−30·0	+32·1	−4·1	−11·5	+10·2	+1·0

It has been seen that variations in the time of felling relative to seed years and to the germination of the seed partly explain the differences in stocking from compartment to compartment. But there are also sharp contrasts between different adjacent vegetation types within the same compartment. In general

the main contrast is between the areas with *Molinia* dominant, where regeneration is adequate, and those with *Pteridium* dominant, where regeneration is very patchy and in general inadequate. Neither the *Molinia* nor the *Pteridium* communities are themselves uniform, however, and conditions in each will be examined in turn.

TABLE X. *Percentage of quadrats in which various species occurred in 1942 and 1943*

	Compartment 8		*Compartments 9 and 14*	
	1942	*1943*	*1942*	*1943*
Calluna vulgaris	0·8	6·5	2·9	4·2
Erica tetralix	0·4	12·0	2·2	13·0
Lonicera periclymenum	3·3	33·0	1·9	25·0
Hedera helix	0·8	0·0	11·0	6·0
Potentilla erecta	0·0	10·0	0·0	1·2
Galium saxatile	3·3	6·5	4·2	14·0
Frangula alnus	..	..	0·32	5·0
Ulex europaeus	..	..	1·3	4·8
Ilex aquifolium	0·4	0·7	0·0	12·0
Quercus robur	3·7	13·0	6·4	14·4
Betula spp.	0·4	4·3	2·6	13·0
Number of quadrats in sample	245	138	211	167

(i) *Molinia type* (cf. Table XI).

In general the *Molinia* areas were well stocked from the beginning, though the great difference in initial stocking between Compt. 8 and Compts. 9 and 14 has already been noted and attributed to the fact that in Compt. 8 the seeding felling followed the germination of 1941 while in Compts. 9 and 14 the felling preceded the germination. The number of new seedlings germinating in 1942, though small, was sufficient to balance deaths among the older seedlings, so that between 1942 and 1943 the total numbers remained steady or even rose slightly. But in 1943 and 1944 scarcely any new seedlings entered, while competing vegetation and beetle attack were taking their toll of the older seedlings, so that there are marked falls in numbers between 1943 and 1944. Thus in Compt. 8 the mean number of '2nd-year and older pine' fell from 0·613 to 0·32 per quadrat, a fall of 48 per cent., while in Compts. 9 and 14 the mean number fell from 1·81 to 1·03, a fall of 43 per cent. From 1944 to 1946 in Compt. 8 the number of '2nd-year and older' fell from 0·32 to 0·26, a fall of 19 per cent., while in Compts. 9 and 14 there was a rise from 1·03 to 1·06. These figures suggest, then, that losses have been distinctly heavier in 8 than in 9 and 14.

It is true that the differences are slight and, in view of the sampling errors involved, may not be significant, but they are in accordance with the field evidence, for it was obvious by 1946 that the carpet of herbaceous vegetation had become much ranker in 8 than in 9 and 14. In Compt. 8 the *Molinia* was dense, with thick tangles of dead foliage filling the spaces between tussocks. *Rubus*

Table XI

	Compartment 8 Molinia					*Compartments 9 and 14 Molinia*					*Compartment 3 Clear-felled*				*Compartment 3 Unfelled*			
	1941[1]	1942	1943	1944	1946	1941[3]	1942	1943	1944	1946	1941[4]	1942	1943	1944	1941	1942	1943	1944
Number of quadrats in sample	53	169	80	50	50	46	114	95	205	85	90	104	84	80	39	46	39	36
Quadrats with 1st-year seedlings.	29	15	0	1	6	42	7	6	6	22	58	5	2	1	16	7	0	0
Such quadrats as percentage of total	55	8·8	0	2	12	9	5·9	6·25	2·93	26	64·5	4·8	2·38	1·25	41	15·2	0	0
Number of 1st-year seedlings	?	16	0	1	10	..	13	8	6	62	172	6	2	1	34	10	0	0
Mean number per quadrat	..	0·095	0	0·02	0·20	..	0·19	0·084	0·029	0·73	1·91	0·058	0·0238	0·0125	0·87	0·217	0	0
Quadrats with 2nd-year seedlings	0	24	24[2]	8[2]	7	0	56	57[2]	92	19	9	66	47	1	2	23	0	4
Such quadrats as percentage of total	..	14·2	30	16	14	..	49·1	59·4	45·3	22	10	63·5	56·0	1·25	5·1	50	0	11·1
Number of 2nd-year seedlings	..	60	49	16	12	..	190	172	212	30	12	205	146	1	2	57	0	6
Mean number per quadrat	..	0·355	0·613	0·32	0·24	..	1·67	1·81	1·03	0·35	0·133	1·97	1·74	0·0125	0·051	1·24	0	0·167
Quadrats with older seedlings	0	0	0	..	9	0	16	..	..	41	0	1	5	35	0	1	21	12
Such quadrats as percentage of total	..	0	0	..	18	..	13·5	..	..	48	0	0·96	5·95	43·8	0	2·17	53·9	33·3
Number of older seedlings	..	0	0	..	13	..	?16	..	..	90	0	1	5	107	0	1	58	24
Mean number per quadrat	..	0	0	..	0·26	..	0·135	..	..	1·06	0	0·0096	0·059	1·34	0	0·0217	1·49	0·667
Quadrats with seedlings any age	29	36	24	?9	17	42	64	57	95	55	61	68	47	37	18	25	21	15
Such quadrats as percentage of total	55	21·3	30	18	34	91	56	59·4	46·3	65	66·8	65·4	56·0	64·3	46·2	54·3	53·9	41·7
Number of seedlings any age	..	76	49	17	35	?219	..	180	218	182	184	212	153	109	36	68	58	30
Mean number per quadrat	..	0·45	0·613	0·34	0·7	?1·92	..	1·90	1·064	2·14	2·14	2·04	..	1·36	0·923	1·48	1·49	0·834

[1] In September before felling. [2] 2nd-year and older. [3] In September. [4] In July.

fruticosus agg. was often mixed with the *Molinia*, and there was little *Calluna* or *Erica tetralix*. Bare litter or humus was rarely exposed except close to the bases of standing trees or old stumps, and even there *Molinia* often grew right up to the side of a stump. By contrast, over most of Compts. 9 and 14 the *Molinia* was mixed to a far greater extent with appreciable amounts of *Calluna*, *Erica tetralix*, *Agrostis setacea*, &c. Between the tussocks were often considerable patches of pine litter, either bare or overgrown with carpets of mosses (especially *Dicranum scoparium* Hedw., *Dicranella heteromalla* Schp., and *Polytrichum formosum* Hedw.) or thin *Galium saxatile*. Old stumps were almost invariably surrounded by a large area of bare litter.

The upper section of Table XII shows the relationship found between stocking and variations in ground vegetation within the *Molinia* type in Compts. 9 and 14 in 1944.

TABLE XII. *Relation between vegetation and abundance of seedlings*

Vegetation	*Number of quadrats in sample*	*Quadrats with seedlings*		*Mean number of seedlings per quadrat*
		Number	*Percentage*	
Molinia associated with *Rubus fruticosus* agg.	37	13	35·2	0·62
Pure *Molinia*	168	82	48·8	1·19
Molinia with *Calluna* and *Erica tetralix* .	19	15	79·0	3·32
Molinia with litter	36	32	89·0	3·92
Pure *Pteridium*	73	20	27·4	0·626
Pteridium–Rubus	77	7	9·1	0·156
Pteridium–Molinia	66	28	42·5	1·20
Pteridium–Calluna	10	8	80·0	5·0

Thus those sites which it must be presumed from the vegetation are most fertile are in fact the poorest from the point of view of regeneration, since they quickly become covered with a closed dense carpet of *Molinia* and herbaceous plants; while on the poorer areas where the closure of the vegetation is slow and *Calluna* and *Erica*, rather than the coarser growing *Rubus*, tend to enter, conditions are much more favourable. *Calluna* and *Erica tetralix* are almost always associated with partially covered humus, and seedlings can grow beneath and through them.

(ii) *Pteridium type* (cf. Table XIII).

In view of the obstacles to the growth of young trees which bracken is known to present, conditions in the *Pteridium* areas are of special interest. As has been seen already, and as the figures in Table XIII show, the areas are in general poorly stocked. This is particularly true of Compt. 8. In Compts. 9 and 14 conditions are very variable. In parts of 14 there are frequent 1st-year seedlings, occasional 2nd-year seedlings, and no older ones, suggesting that seedlings failed to survive longer than 2 years. Actually, over the period 1942–6, in Compts. 9 and 14, the mean number of 1st-year seedlings is appreciably higher in the *Pteridium* than

Table XIII

	Compartment 8 Pteridium					*Compartments 9 and 14 Pteridium*					*Compartment 3 Clear-felled*			
	1941	*1942*	*1943*	*1944*	*1946*	*1941*	*1942*	*1943*	*1944*	*1946*	*1941*	*1942*	*1943*	*1944*
Number of quadrats in sample	..	75	58	50	50	..	97	72	226	60	14	14	14	14
Quadrats with 1st-year pine	..	5	2	1	1	..	13	1	2	28	10	2	0	0
Such quadrats as percentage of total	..	6·7	3·45	2	2	..	..	1·4	0·885	47	71	14	0	0
Number of 1st-year seedlings	..	6	2	1	1	..	16	2	2	89	31	2	0	0
Mean number	..	0·08	0·035	0·02	0·02	..	0·165	0·028	0·0089	1·48	2·21	0·143	0	0
Quadrats with 2nd-year pine	..	5	10[1]	8	11	..	53	21[2]	62	18	2	12	11	0
Such quadrats as percentage of total	..	6·7	17·3	16	22	..	54	29·2	27·4	30	14	86	79	0
Number of 2nd-year seedlings	..	13	25	12	15	..	137	64	197	32	..	53	41	0
Mean number	..	0·173	0·431	0·24	0·30	..	1·41	0·89	0·871	0·53	..	3·79	2·93	0
Quadrats with older pine	..	0	0	..	3	..	5	..	..	18	0	0	0	10
Such quadrats as percentage of total	..	0	0	..	6	..	5·2	..	..	30	..	..	..	71
Number of older seedlings	..	0	0	..	4	..	5	..	..	35	0	0	0	30
Mean number	..	0	0	..	0·08	..	0·052	..	..	0·583	..	..	..	2·14
Quadrats with seedlings any age	..	9	11	?9	13	..	60	21	63	39	11	13	11	10
Such quadrats as percentage of total	..	12	19	18	26	..	62	29·2	..	65	79	93	79	71
Number of seedlings, any age	..	19	27	13	20	..	158	66	199	156	33	55	41	30
Mean number	..	0·254	0·466	0·26	0·4	..	1·63	0·92	0·880	2·60	2·36	3·93	2·93	2·14

[1] 2nd-year and older.

[2] 2nd-year and older in 1943 and 1944.

in the *Molinia* areas, though the number of older seedlings is less (Table XIV). By contrast, in parts of the east of Compt. 9, *Pteridium* areas were as well stocked as *Molinia* areas, while in Compt. 3 the *Pteridium* area was actually better stocked.

TABLE XIV. *Mean number of seedlings per quadrat, 1941–6 inclusive*

	Compartment 8		*Compartments 9 and 14*	
	Molinia	*Pteridium*	*Molinia*	*Pteridium*
1st-year seedlings . .	0·075	0·043	0·178	0·240
Older seedlings . .	0·393	0·296	1·42	1·03

As in the *Molinia* areas, the variations in stocking are to a large extent correlated with variations in the composition of the vegetation, as is shown by the figures in the lower section of Table XII.

Here, as in the corresponding figures for the *Molinia* types, each quadrat has been allotted to its vegetation type on the basis of the cover-composition of the individual quadrat, that is to say, all quadrats where *Rubus* is present with *Pteridium* have been allotted to the *Pteridium-Rubus* type. But the relation of density of stocking to composition of ground cover is so close that it is shown in other ways. There are regional variations in stocking, so that some transects have smaller amounts of regeneration; and, as Table XV shows, these variations are associated with variations in ground cover. The abundance of seedlings varies directly with the cover by moss and litter, and inversely with the cover by *Rubus* and *Pteridium*. That it varies directly with the cover by *Molinia* shows that seedlings tend to occur in places where *Molinia* is dominant rather than places where *Rubus* or *Pteridium* is dominant.

TABLE XV. *Compartments 9 and 14, 1943*

Transect no.	*Percentage of quadrats with seedlings*	*Molinia*		*Rubus*		*Pteridium*		*Moss and litter*	
		a	*b*	*a*	*b*	*a*	*b*	*a*	*b*
1. *Molinia type*									
I	50·0	15	29·7	25	30·0	..	..	10	19·2
II	62·5	40	41·0	3	13·0	..	..	37	29·7
III	72·7	63	53·7	10	9·5	..	..	21	29·0
2. *Pteridium type*									
II	9·0	9	15·0	36	31·8	32	24·8	36	33·6
I	22·0	17	17·2	17	23·9	28	31·5	39	37·8
IV	32·5	31	27·7	0	12·3	54	48·5	54	53·1
III	58·0	32	31·4	0	18·4	41	35·9	73	60·4

a = percentage of quadrats with cover of 50 per cent. or more.
b = mean percentage cover per quadrat.

Most of the frequency distributions of cover classes are too skew to permit of their being treated by the usual statistical methods, but those of *Molinia*

in Compts. 9 and 14 seem sufficiently normal. The probability of chance occurrence of the variations in the mean cover of *Molinia*, as shown by analysis of variance, is less than 0·001.

Once again, as in the *Molinia* areas, those vegetational types which from the evidence of the vegetation would be expected to have the highest fertility are the poorest from the point of view of regeneration. There is again evidence of greater mortality in Compt. 8 than in Compts. 9 and 14. The mean number per quadrat of 2nd-year and older pine in 8 (Table XIII) fell from 0·43 in 1943 to 0·24 in 1944, a loss of 44 per cent., while in 9 and 14 the fall from 0·89 to 0·87 was one of just over 2 per cent. Comparison of the figures for '2nd-year and older' pine in 1944 with '3rd-year and older' in 1946 (Tables XI, XIII, and XVI) shows the same feature still more strikingly. Neglecting the sampling error, it appears that in Compt. 8 at least 80 per cent. of the seedlings present in 1943 had disappeared by 1946, whereas in Compts. 9 and 14 not more than 25 per cent. had disappeared.

TABLE XVI. *Number of pine (3rd year or older) in 1946 relative to number of pine (any age) in 1943*

		Percentage of quadrats stocked	*Mean number of seedlings*	
			Per quadrat	*Per stocked quadrat*
Compt. 8	*Molinia*	0·6	0·426	0·713
	Pteridium	0·316	0·17	0·54
Compt. 9	*Molinia*	0·814	0·558	0·696
	Pteridium	1·03	0·783	0·762

Moreover, in Compt. 8 the proportion lost has been far greater in the *Pteridium* than in the *Molinia*, whereas in Compts. 9 and 14 the death-rate in the two types differed little, but was, if anything, a little lower in the *Pteridium*. The number of new seedlings entering has also been less in 8 than in 9 and 14, though this must be partly attributed to the poorer seed supply.

In general the *Pteridium* of Compt. 8 differs from that of Compts. 9 and 14 in much the same way as does the *Molinia*. In Compt. 8 it is dense and tall, and beneath it the ground is usually covered with a thick tangled loose litter of dead fronds; and some *Rubus fruticosus* is often present. In Compts. 9 and 14 several different conditions exist, but only locally is the *Pteridium* as dense and tall as in 8. First-year seedlings were found beneath *Pteridium* only where it has not formed an accumulation of loose litter. In many places there are thinly scattered small tussocks of *Molinia* amongst the *Pteridium*, with plenty of firm, bare humus exposed, and these conditions appeared to be specially favourable. It was, however, a striking fact that in some areas 1st-year and very weak etiolated 2nd-year seedlings were frequent; but there was nothing older, implying that the seedlings failed to survive for more than 2 years. There were, however, areas in Compt. 9 where older seedlings amongst *Pteridium* were abundant, and there

seems every reason to believe that regeneration will be successful despite the bracken.

The transect through Compt. 3 is specially interesting from this point of view. Here the bracken forms an irregular belt on rising ground at the outer edge of the *Molinia* zone. Only 14 quadrats fell in the *Pteridium*, but by 1943 it was obvious that these were much better stocked than adjacent *Molinia* ground. More extensive assessments in 1944 showed that this appearance was not a sampling error but that locally, in Strip 2 at least, the *Pteridium* ground was better stocked than adjacent *Molinia* ground. This is demonstrated by the figures in Table XVII, which give the numbers of stocked quadrats and numbers of seedlings in random samples of 25 quadrats.

TABLE XVII. *Relative abundance of seedlings in Pteridium and Molinia ground in clear-felled strips, Compartment 3, 1944*

	Strip 2		*Strip 4*	
	Pteridium	*Molinia*	*Pteridium*	*Molinia*
Number of stocked quadrats	14	14	5	9
Percentage of stocked quadrats . . .	56%	56%	20%	36%
Number of seedlings	58	44	8	18
Mean number of seedlings per quadrat . .	2·32	1·76	0·32	0·72

Probably this is to be explained by the condition of the ground at the time of felling. In the unfelled stand there is variation comparable with that seen, after felling, in the ground vegetation. In some areas the *Pteridium* is 4 to 5 ft. tall and correspondingly dense. Under such conditions there is beneath it a dense tangle of dead fronds, often mixed with it, conditions which no seedling can survive. In other places, however, where the bracken is only about 2 ft. high and there is no loose accumulation of dead bracken fronds on the ground, the bracken areas offer greater surfaces of bare pine litter suitable for seedling growth than do the *Molinia* areas, and consequently conditions are at least as favourable as in the *Molinia*.

This point is demonstrated by the figures in Table XVIII, in which neighbouring *Molinia* and *Pteridium* areas are compared.

The first two pairs of samples are from the unfelled strips which alternate with the clear-felled strips of Compt. 3. Here, where strong sidelight permits survival of seedlings, there is little difference in stocking between the bracken and the *Molinia* areas. In the first sample the bracken area appears the better stocked, but sampling errors are large and the difference is doubtless insignificant. The second two pairs are from the intact stand, north of Compt. 3, where site conditions are probably similar. Here again the cover of litter, or at least litter+moss, is greater in the *Pteridium* areas, but the stocking is poorer, probably because the shade cast by the *Pteridium* prevents survival of seedlings for more than a year. It is obvious, however, that if such an area were felled at the time of a seed year, the conditions would be more favourable in the *Pteridium*, especially if

TABLE XVIII. *Comparison of Molinia and Pteridium ground vegetation beneath unfelled pine*

	No. of quadrats in sample	Mean percentage cover of				No. of stocked quadrats	Percentage of stocked quadrats	No. of seedlings	Mean no. of seedlings per quadrat
		Pteridium	Molinia and Rubus	Litter	Moss				
Unfelled strips, Compt. 3	25	0	27·2	36·4	27·2	17	68	48	1·92
	25	38	12	50·6	35·4	18	72	61	2·44
	20	0	37·5	48·75	11·25	18	90	78	3·9
	20	37	13·25	63·25	14	16	80	59	2·95
Intact stand in Compt. 2	40	0	39	45·75	15·25	19	47·5	73	1·825
	40	39·1	26	41·1	32·9	5	12·5	6·0	0·15
	40	0	47·7	31·6	20·6	24	60	..	..
	40	37·0	21	48·0	30·7	8	12·5	..	..

felling and extraction took place at such a time of the year as to break the young fronds. It will be noted (Tables XI and XIII) that the number of 1st-year seedlings recorded in 1941 and 1942 was greater in the *Pteridium* of Compt. 3 than in the *Molinia*. The areas of well-stocked *Pteridium* in Compt. 9 are probably to be explained in a similar way.

Subsequent progress of regeneration amongst bracken will depend on the rapidity with which bracken increases in height and density after felling. As has been mentioned, it seems as though pine seedlings could not survive beneath continuous bracken for more than 2 years: and even pine plants which germinated immediately after the felling in 1940, when the bracken was still thin, were suffering from its competition, as the measurements of the lengths of leading shoots given in Table XIX and in Fig. 5 show.

TABLE XIX. *Comparison of lengths of leading shoots of pine amongst Molinia and Pteridium*

	Number in sample	Mean length of shoot	Standard deviation of observations	Probability of difference between means arising by chance
1943. Compts. 9 and 14 *Molinia*	204	7·43	11·3	*c.* 0·01
1943. Compts. 9 and 14 *Pteridium*	180	6·70	5·5	
1944. Compt. 3 *Molinia*	66	6·08	6·38	0·01
1944. Compt. 3 *Pteridium*	56	4·34	6·26	

Amongst *Molinia* the pine seedlings are also much more robust, a fact which is difficult to demonstrate by figures but is very obvious to the eye.

Other causes of death. While suppression is undoubtedly an important cause of death, it is not the only one. The beetles *Hylastes* and *Hylobius* were causing

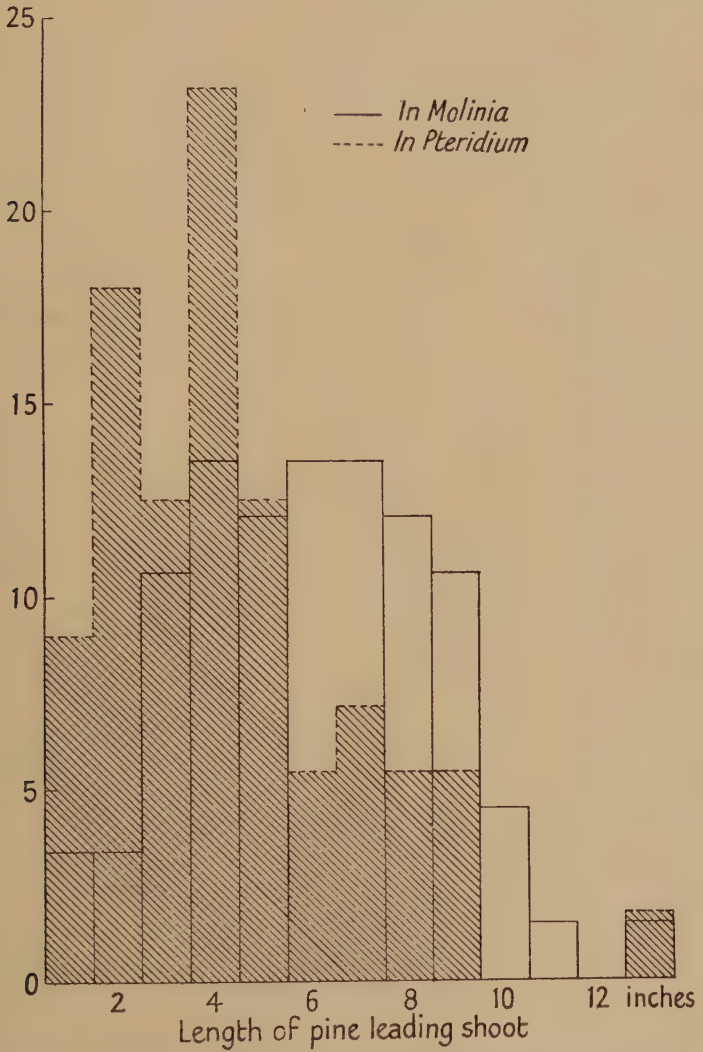


Fig. 5. Frequency distribution of lengths of pine leading shoots amongst *Pteridium and Molinia.* Compt. 3, clear-felled strip 1944.

considerable losses in 1943, when about 4 per cent. of the 2- and 3-year-old seedlings in about 7 per cent. of the quadrats were dying from their attacks.

The success of the regeneration. In deciding whether the existing crop of seedlings is sufficient, the spacing of quadrats containing seedlings is more important than the total number of seedlings, since on an area as small as 4 sq. ft. not more than one pine would be expected to survive to maturity. The simplest

way of calculating an approximate figure for stocking is to take the number of stocked quadrats per 400 sq. ft. as the percentage density of stocking. A more vivid comparison with the familiar conditions in plantations is given by calculating the average spacing. Some of these figures are given in Table XX.

TABLE XX. *Average spacing of stocked quadrats, in feet*

Compt.	*Quadrats with seedlings of*	*Vegetation*	*1943* *Mean for whole block*	*1943* *Poorest transect*
8	Pine only	*Molinia*	3·64	4·35
		Pteridium	4·58	∞
8	Pine, Douglas fir, or oak	*Molinia*	3·15	3·56
		Pteridium	3·24	∞
9 and 14	Pine only	*Molinia*	2·59	2·82
		Pteridium	3·70	6·67
9 and 14	Pine, Douglas fir, or oak	*Molinia*	2·52	2·76
		Pteridium	3·15	3·55

Except for some areas of *Pteridium* these densities appear to be adequate, especially in view of the fact that there are also seedlings of Douglas fir, oak, and birch which could be used to fill up gaps. Approximately a third of the area is covered by *Pteridium* types, and comparison of the transects shows that of this about a third is very poorly stocked or blank.

It might happen that groups of seedlings survived more frequently than isolated individuals, and in such a case it would be necessary in estimating the adequacy of regeneration to neglect quadrats containing very few seedlings and consider only the distribution of quadrats containing several seedlings. As has been shown earlier, the distribution of quadrats containing more than four seedlings can be considered as random, and the average spacing of such quadrats is given in Table XXI.

TABLE XXI. *Average spacing of quadrats with more than four seedlings, 1943*

	Size of sample		*Number of quadrats with 4 or more seedlings*	*Average spacing of quadrats with 4 or more seedlings*
	Number of quadrats	*Sq. ft.*		
Molinia type				ft.
Compts. 9 and 14, 1943. .	82	328	11	5·5
Compt. 8, 1943 . . .	76	304	4	8·7
Pteridium type				
Compts. 9 and 14, 1943. .	72	288	7	6·4
Compt. 8, 1943 . . .	58	232	2	10·8

Even by this standard the stocking is reasonable in the *Molinia* areas but poor in the *Pteridium* areas of Compt. 8.

So far, the belt of Douglas fir along the stream, together with the strips of former oak and oak–pine fringing it, have been neglected. Felling was not carried out there until 1942–3, and there has been no considerable supply of pine seed since, so that they remain very poorly stocked. Beneath the Douglas fir, even after the thinning, shade would still be too dense to permit the survival of pine, even though about 40 per cent. of the quadrats in this region carried pine in 1946. The oak, on the other hand, has been clear felled, but pine seedlings remain very scarce in the areas where the oak grew, suggesting that for pine as for Douglas fir [cf. Jones, 1945 (3)] the associated mull humus and herbaceous vegetation do not provide a very satisfactory seed-bed.

GENERAL SUMMARY AND DISCUSSION.

Natural regeneration in Busketts Lawn has been successful on the whole. Only about a third of the *Pteridium* areas—perhaps a ninth of the whole area—is completely blank, and much of the rest is well stocked. Regeneration has been best with the strip fellings of Compt. 3, but this is probably because extraction operations were completed there at a slightly earlier date than elsewhere. Nevertheless, where in the intact strips the density of the stand is such as to keep ground vegetation very scanty, while strong side-light permits the establishment of abundant pine seedlings, the strip system might offer the possibility of easier and more copious regeneration than the shelterwood system. Such conditions seem to prevail locally in the strips in Busketts Lawn Inclosure, but it is obvious that to take advantage of them care would be needed in extraction and felling.

In regenerating mixtures by the shelterwood system, in continental practice, Scots pine seed-bearers are commonly left until the last, so that the Scots pine can seed up any blanks which other species have failed to colonize. This procedure is necessary, of course, because of the need of Scots pine for abundant light; but it also seems to imply an ability of Scots pine to establish itself amongst competing herbaceous vegetation, an ability which might also be expected from the ease with which it appears to colonize heath communities. Scots pine in the New Forest has seeded up many unsatisfactory plantations of species such as Sitka spruce and Douglas fir, where the original species has failed to grow, apparently establishing itself in dense mixtures of *Molinia*, *Calluna*, &c. It is therefore all the more striking that the present work seems to stress the sensitivity of the pine to competing vegetation, and points to the necessity of bare spots of humus or mineral soil for the establishment of seedlings. There is a very close relationship between the density of phanerogam cover (Table XV, Fig. 4) and the abundance of seedlings, and between this latter and the composition of the phanerogam cover (Table XII). There is evidence of ability to enter closed vegetation only beneath *Calluna* and *Erica tetralix* bushes (p. 167; cf. also the large numbers of seedlings associated with presence of *Calluna* in Table XII), and it might be suspected that when pine colonizes closed and apparently dense

communities it is only able to do so beneath old 'leggy' bushes of *Calluna* or similar shrubs. In a recent experiment at Oxford in which a number of species were grown with and without the competition of coarse grasses, Mr. J. Chinner found that the growth of Scots pine was more strongly depressed by competition than was the growth of any other species (unpublished).

It seems obvious that the degree of success attained in the regeneration of Busketts Lawn Inclosure is largely attributable to the fact that the seeding fellings coincided with a mast year. Moreover, the ease of regeneration is intimately related to the speed with which the ground becomes covered by rank-growing species such as *Molinia*, *Rubus fruticosus*, and *Pteridium*. Where such regrowth is slow (e.g. Compts. 9 and 14) the seeding felling could be made with impunity at any time; but where regrowth is rapid (e.g. Compt. 8) it becomes much more important that the felling should coincide with a good seed year. The behaviour of the ground vegetation after felling could doubtless be predicted, given a sufficiently intimate knowledge of the region, but it is clear that very slight differences in site may induce important differences in behaviour.

There seems to have been an almost complete cessation of seed production for a few years following the seeding felling in the shelterwood regeneration areas. It is not clear whether this was caused by the felling or was merely due to normal periodicity of seed years. The evidence from estimates of cone production suggests the former, that from counts of seedlings the latter. Cessation of seed production by seed-bearers as the result of a seeding felling does not seem to be recorded in the literature, but there is some evidence that oak behaves in this way in the New Forest. In either case a period of 5 to 6 years elapsed before there was any indication of an increased seed supply, and during this time the continued growth of the ground vegetation has been reducing the possibility of filling up blanks. Both *Molinia* and *Pteridium* have grown up more rapidly and densely in Compt. 8 than in Compts. 9 and 14. It is very unfortunate, in view of this fact, that Compt. 8 was not only felled at a less satisfactory time of the year, but that the trees left as seed-bearers had poorer crowns which have borne poorer crops of seed. Fortunately, intact blocks of pine remain standing on three sides of the compartment, and there is evidence that seed from these is contributing largely to its new regeneration.

The variations in composition of ground vegetation and the differences in its luxuriance are doubtless caused by soil variation, and it is instructive to note that in 1787, before afforestation, Compt. 8 was 'good pasture', while Compts. 9 and 14 were 'wet in winter' and needed draining. This difference in water relations, though no longer obvious to the eye, probably explains many of the differences between the two areas. Dense and luxuriant *Molinia* prevents the entry of fresh pine seedlings at least as effectively as *Pteridium*, but is less likely to suppress established pine seedlings. Where *Pteridium* is dense and tall it offers a great obstacle both to germination and to later growth of pine. With less luxuriant *Pteridium*, where there is no great accumulation of dead fronds on the ground, conditions are relatively favourable for germination, and seedlings may survive until their 2nd year but are ultimately suppressed. Presumably when such

areas have a good stocking of well-established seedlings they were established while the *Pteridium* was still very open.

Despite many irregularities the *Pteridium* areas fall into two broad groups as regards position: those near the stream, just outside the Douglas fir belt, and those on higher ground farther from the stream. In the former group, which predominates in Compt. 8, the *Pteridium* is luxuriant. In the latter group, which is more abundant in Compts. 9 and 14 and alone is represented in Compt. 3, the *Pteridium* is shorter and more open. In these latter areas whipping the *Pteridium* in early summer several times would probably cause the blanks to fill up; in the former areas the accumulated litter would have to be removed as well.

SUMMARY.

Scots pine (*Pinus sylvestris* L.) has been successfully regenerated in Busketts Lawn Inclosure (New Forest, Hampshire) both by shelterwood fellings and by clear felling alternate strips in 1940–2. Success has been due primarily to the coincidence over most of the Inclosure of the seeding felling with a good seed-year. There does not appear to have been another good seed-year until 1945 (germination of 1946). The study emphasizes the importance of keeping trees with well-developed crowns for seed-bearers.

Although Scots pine is often regarded as a tree with considerable ability to enter closed communities, the seedlings appear to enter only where there is bare humus, mineral soil, or some kinds of moss carpet, and their abundance is intimately related to the composition of the ground-cover. In general, communities dominated by *Molinia coerulea* are more favourable to pine regeneration than communities dominated by *Pteridium aquilinum*; but under some conditions, where *Pteridium* is not vigorous it may be more favourable than *Molinia* in the early stages, though not necessarily so for the later growth of the pine seedlings. Admixture of either *Pteridium* or *Molinia* with *Calluna vulgaris* is correlated with more favourable, and admixture with *Rubus fruticosus* agg. with less favourable conditions. The slightly more vigorous growth of both *Pteridium* and *Molinia* over Compt. 8, as compared with Compts. 9 and 14, appears to result in poorer conditions for entry of pine seedlings, as well as higher mortality. Although there is at present no obvious soil difference between these two areas, it is known that in the eighteenth century, before afforestation, the vegetation of these two areas was different, Compts. 9 and 14 then being wet heath.

ACKNOWLEDGEMENTS.

Although the writer is entirely responsible for the preparation of this account and for any conclusions, the amassing of the observations has been a communal effort. The inception of the study was largely due to Professor H. G. Champion. Mr. A. Foggie generously contributed the whole of his own records extending over three years, while the relatively extensive and elaborate assessments would have been impossible without the help of the students of the Imperial Forestry Institute. Mr. J. Holownia has allowed me to use some of his observations made in the spring of 1947.

To all these friends and colleagues who have contributed, and to Mr. D. W. Young, Deputy Surveyor of the New Forest, and his staff, the writer wishes to extend his thanks and acknowledge his indebtedness for their collaboration.

LITERATURE REFERENCES.

(1) Holownia, J. (1947): *Scots Pine Regeneration in the New Forest.* Unpublished diploma thesis, Imperial Forestry Institute, Oxford.

(2) Jones, E. W. (1943): 'The Cone Production of Scots Pine Seed-bearers'. *Forestry*, xvii. 52–4.

(3) —— (1945): 'The Regeneration of Douglas Fir, *Pseudotsuga taxifolia* Britt., in the New Forest'. *J. Ecol.* xxxiii. 44–56.

(4) Richardson, King, Driver, and Abraham (1787): *A Survey of the New Forest.* MS., with accompanying printed maps.

VOLUME ESTIMATION OF STANDING TIMBER BY SAMPLING

By D. J. FINNEY

(*Lecturer in the Design and Analysis of Scientific Experiment, University of Oxford*)

1. INTRODUCTION.

THE time and labour required for the complete enumeration of every tree in a forest area, in order to assess the total volume of timber, are so great that any method promising to give useful results more economically merits careful examination. The more conservative may still believe that the estimation of timber volume from enumeration of a sample of the stand is never sufficiently reliable, but all must agree that any decision against sampling, a procedure now adopted as routine in many branches of applied science, must be taken only after the fullest consideration of the claims made by those experienced in sampling practice. No complete bibliography of forest sampling will be attempted here, but as examples of the firm conviction that estimation by sampling is of great importance, and as representative of widely different conditions, recent publications by Griffith [1945 *a–g*, 1946 *a–c* (6) to (15)], Hasel [1938 (16)], Ilvessalo [1942 (17)], Matérn [1947 (20)], and Schumacher and Chapman [1942 (22)] may be quoted.

The present writer is himself convinced that the advantages of sampling usually far outweigh the disadvantages, and he is in complete agreement with the conclusion reached by Griffith [1946 *c* (15)], after extensive investigation of sampling results, that 'Intensive and expensive 100% enumerations are NOT necessary in order to obtain a reasonable estimate of the growing stock'. Nevertheless, he finds that arguments on both sides are frequently confused by failure to keep clear the fundamental principles involved; more particularly is this so when the relative merits of different forms of sampling are under discussion. Amongst those engaged in sampling investigations who have little personal knowledge of statistical science, opinions range between two extremes: some contend that sampling requires none but the most elementary statistical ideas, and that the practical man needs no assistance from the professional statistician; others embarrass the statistician by unquestioning faith that, without any data or previous knowledge of the investigation projected, he can state exactly what procedure must be followed in order to obtain a result of specified accuracy. Neither view is correct. The statistician who ignores the practical difficulties of sampling is unlikely to make acceptable recommendations, and the analysis of numerical data as well as the application of statistical theory is essential to the solution of almost every sampling problem; on the other hand, both the principles and the practice of sampling involve logical points of some subtlety and, occasionally, advanced statistical theory.

Almost always in a sampling investigation, many decisions on procedure have to be taken on considerations of convenience and practicability. Available time and labour are limited, and sampling schemes that on paper appear to be the most efficient may have to be rejected because they are beyond the capabilities of the field workers responsible for their execution. Other decisions, especially those relating to the size and distribution of sampling units, may be taken purely on statistical grounds; these may be subdivided into questions which may be settled by reference to general statistical theory, and questions requiring the detailed analysis of extensive series of typical numerical data, from which principles of good sampling appropriate to the material studied may emerge. There are no rigid boundaries between the types of problem, but some such classification seems essential to a proper understanding of the present situation.

Many recent publications have discussed the mathematical and statistical theory of sampling, many others have described the technique of sampling and the analysis of data from sampling studies, though often the latter show a lack of critical appreciation of the statistical problems. The writer hopes that in this paper he has not entirely lost sight of practical considerations, but his chief concern is to bridge the gap between earlier publications by describing in simple language the statistical requirements for a sound sampling procedure and by indicating what the statistician can and what he cannot do. The paper is also intended as an introduction to a second, now in preparation, in which some problems of systematic sampling will be discussed more fully. Much of what follows may seem very elementary: the logical problems of sampling are generally more difficult than the mathematical, and clear definition of the concepts and terminology is a necessary preliminary. The illustrations have been deliberately simplified so as to emphasize statistical points without inessential complicating factors; for example, the sampling of an area of irregular outline is not different in principle from the sampling of a rectangular area, but discussion of the practical complications would obscure the main purpose of this paper.

2. THE OBJECTS OF ESTIMATION.

Before discussing methods of sampling, some consideration of objectives is important. The statistician, engrossed in calculations of standard errors and relative efficiencies, is sometimes in danger of forgetting that the chief object of any procedure he may recommend is the attainment of a figure which shall be, as closely as possible, the total volume of timber in a given stand. Instead of total volume, attention may be restricted to certain species of tree or to certain qualities of timber, without essentially altering the problem, except that, if several different species or qualities have to be estimated simultaneously, selection of a procedure which shall be adequate for all may entail some compromise and departure from the optimal conditions for any one.[1] Assuming that the total

[1] This paper has been written with reference to the volume of timber in the stand, but the methods discussed and the arguments used are equally applicable to other quantitative measurements. In particular, estimation of the total number of trees or of the number in a certain category

area is known, estimation of total volume is equivalent to estimation of volume per unit area, a figure which is often more convenient in comparisons between stands.

A second object, important but necessarily less so than the first, is the obtaining of some measure of the precision of the volume estimate, preferably in conventional statistical terms of standard error and fiducial limits, otherwise as a statement that the errors are almost certainly less than a specified amount. An estimate based upon complete enumeration of every part of a stand should be correct within the limits of accuracy of measurement, apart from mistakes of those responsible for the enumeration. It will be assumed here that the workers are sufficiently reliable, and their instructions sufficiently clear, for such mistakes to have a negligible effect upon the estimate.[1] No amount of statistical analysis can remove the effects of gross carelessness in the field or of ambiguities in the instructions to field workers (cf. section 5). The word 'error' in this paper will be reserved for its purely statistical connotations. In a sampling enumeration, on the other hand, the final estimate will deviate from the true volume of the stand by an amount which is compounded of mistakes in procedure (if any) and statistical 'error' or variations attributable to the selection of the sample from the whole. The second component will not be negligible, except by a chance fortunate selection, unless the sample forms a very large proportion of the whole; it cannot be measured exactly without knowledge of the true figure. It is possible, however, under conditions to be discussed later, to make probability statements about the magnitude of the error, and so to assert that the estimate is unlikely to deviate from the true value by more than a certain amount.

Whether the enumeration is complete or partial, the data will usually be recorded as volumes on small units of area, each of perhaps 1 acre or other convenient size. A third use to which the data may be put is in the preparation of a map of the forest, showing regions of high and low volume per unit area (or, indeed, in ordinary topographical mapping of an unknown region). The only requirement in order that the results of a complete enumeration may be adapted to this use is that a suitably small recording unit shall be chosen. In a partial enumeration, however, the optimal sampling procedure for volume estimation will not necessarily be the same as the optimal for mapping. The two problems are entirely different, and indeed to specify optimal conditions for mapping would not be easy. The conflict between the two cannot be resolved by the statistician, but only by a decision as to which is the prime object of study. This paper is

could be considered in the same way, though of course the optimal procedure for tree volume need not be the same as that for number of trees or other characteristic.

[1] 'The reduction of these errors to a minimum is a local concern. Such errors are often due to using an inexperienced and underpaid staff with inefficient supervision. They are due for example to using badly adjusted callipers, cheap and badly mended measuring tapes, poor estimation of height, failure to keep the correct width of the enumeration strip, failure to measure every tree in the strip, misidentification of species in mixed forest, etc., etc.' [Griffith, 1945 *a* (6)]. '*Errors which are personal to the enumerating party cannot be eliminated but every possible step should be taken to reduce them to a level where they are negligible in comparison with errors of estimation from other sources*' [Griffith, 1945 *c* (8)].

concerned with volume estimation, and, though the great importance of mapping is not denied, no more than occasional references to it will be made in succeeding sections.

3. COMPLETE AND PARTIAL ENUMERATION.

The relative merits of complete and partial enumeration in timber estimation, as for many other types of census and survey, have been debated frequently. Partial enumeration, by means of sampling, has no absolute advantage over the complete enumeration of every tree, and indeed, as has already been pointed out, must always give less information than the forest could provide since inevitably a sampling estimate will be in error to an unknown extent. If resources of labour and time were unlimited, complete enumeration would invariably be preferred.

In fact, the choice is seldom so simple. Usually the time or labour available for obtaining estimates of certain stands is limited and its most economical allocation must be considered. Were a complete enumeration of one stand to be undertaken, all information on other equally important stands might have to be abandoned. Sampling methods offer, as an alternative, the partial enumeration of each stand and the consequent obtaining of some information on the volume for each. Decision between the two must rest upon particular circumstances; clearly neither is entirely satisfactory, but, when limited resources forbid complete enumeration everywhere, no third course is open. The question of what is lost by any sampling scheme therefore deserves careful study.

To those who would deny all validity to the sampling method it may be pointed out that a satisfactory estimate could always be obtained providing that the sample were made a sufficiently large proportion of the whole. As an extreme illustration, if a sample consisting of 95 per cent. of a forest were enumerated, precautions being taken to ensure that the other 5 per cent. did not differ violently in character, most of the information has been obtained in full and the omission of the small part cannot be seriously detrimental to the estimate of volume. There can be no fundamental invalidity in the sampling approach if a large sample can be regarded as trustworthy, but clearly a 95 per cent. sample gives no appreciable saving of labour over a complete enumeration. Even a 50 per cent. sample is too large in general to be a great economic gain, and if sampling techniques are to be of practical value in timber estimation they must lead to estimates of sufficient reliability for commercial use when 10 per cent. or less of the total area of forest is enumerated.

Here statistical argument and analysis are essential. General statistical principles may suggest certain types of sampling procedure as likely to prove more effective than others. Paradoxically, however, the ideal sampling scheme for a particular stand, using resources to best advantage, could be decided only on the results of a complete enumeration of the same stand! Since this is scarcely a practical policy, recourse must be had to the evidence provided by existing records for similar areas. The records of a complete enumeration, if collected separately for many small units of area, can be used to show what precision would

have been obtained by different sampling schemes. Records of random sampling surveys also may serve to indicate the sampling variation that would occur in future similar surveys, and may even give valuable information on the sampling variation corresponding to other sampling procedures, which differ from that actually used in respect of the total area enumerated or the distribution of sampling units. There can be no assurance that the results of one survey will prove a reliable guide to the precision obtainable in the sampling of other closely similar stands, still less to that for areas of very different forest type or in a different part of the world. Nevertheless, the examination of extensive collections of numerical data should add to knowledge of the nature and magnitude of variations in volume per unit area so that future recommendations on sampling may rest on a sounder basis than those of to-day.

4. TERMINOLOGY.

In the literature of sampling, the terminology for various concepts and methods varies from one author to another. No writer to-day can make his usage agree with that of all his predecessors, but he can at least attempt to be consistent in his own practice. Appreciation of the definitions given in this section should help to remove one source of difficulty in a confusing subject. Inevitably the terminology adopted here reflects a personal opinion of what is best, though it is thought to be in general accord with that now current.

The boundaries of a forest area will seldom be regular, but irregularities serve only to complicate the arithmetic of sampling without altering essential ideas. The arithmetical analysis of sampling records has been described often, and the modifications required for dealing with irregular forest boundaries have been given, for example, by Schumacher and Chapman [1942 (22)]. For the present purpose this complication may be ignored. The ensuing discussion will be with special reference to an illustrative example, taken as a rectangular stand of 10,000 acres, 1,000 chains long and 100 chains wide, in which only one category of timber is to be estimated. The stand will be supposed natural forest, so that there are no regular lines of planting.

By a *complete enumeration* is understood a determination of the total volume of timber in the stand from measurement of every tree. A *sample enumeration*, on the other hand, is a measurement of some portion of the 10,000 acres, comprising, say, A acres in all; on this is based an estimate of total volume, obtained by multiplication of the volume on the A acres by $10{,}000/A$. The A acres are a *sample* of the whole, and the ratio of their area to that of the whole stand, $A/10{,}000$, is the *sampling fraction* or *intensity of sampling*.

The A acres forming the sample will usually be enumerated in a number of smaller *sampling units*. The distinction between the sample and the sampling units of which it is formed must be kept clear; in this paper it will be strictly maintained, though other writers have often referred to each sampling unit as a 'sample'. In forest sampling, a sampling unit will normally be an arbitrarily defined small area. For example, the unit might be a rectangle of 5 chains × 2 chains, so that the sample would contain A units; alternatively the unit might

be a strip across the stand, 2 chains in width and therefore 20 acres in area, so that the sample would contain $A/20$ units. A sampling unit may be an arbitrary subdivision of the stand, as here, or a naturally occurring unit of the material sampled. A sampling unit is not necessarily a single compact area, but can consist of several small areas at fixed distances apart; for example, a 10-acre sampling unit could consist of two rectangles, each 10 chains × 5 chains, separated by an equal unsampled area.[1] Yates and Zacopanay [1935 (27)] have illustrated different types of complex unit for sampling drilled field crops, and some of their patterns might be adapted to forest sampling. Sampling units need not all be of the same size, but that possible complication can be omitted from the present discussion. A necessary condition for assessment of the precision of a sample estimate of volume to be possible is that separate records for the sampling units should be available;[2] though experience may show that, in some circumstances, a reasonably reliable prediction of the precision of a projected sampling scheme can be made in advance from examination of results of earlier similar investigations, a figure appropriate to the results of the new enumeration can never be derived from the total alone.

The ultimate units of area in which details of an enumeration, complete or sample, are recorded are the *recording units*. These are either identical with or smaller than sampling units: they are the atoms of which the sampling unit molecule is formed. For example, if the sampling unit were a square of 10 chains × 10 chains, this might itself be the recording unit; for a sampling unit consisting of a strip 100 chains × 2 chains, each 5 chains length of strip might be separately recorded, so that each sampling unit would contain 20 recording units. Subdivision of a sampling unit into recording units corresponds to what Griffith [1945 *a*, *b* (6) and (7)] terms closure of the enumeration book. In any one survey, recording units will normally be all of the same size, though for the purposes of the survey alone this is not essential. Section 9 will make clear that neither the estimate of total volume nor the assessment of its precision can be affected by the manner in which the sampling units are divided into recording units. Both the estimate of total volume and the assessment of its precision depend only on the complete sampling units. Detailed figures for recording units, however, apart from any additional convenience in the field, assist the investigation of the precision that might have been found under a different system of sampling, and so may aid the improvement of sampling technique. Data from a sample enumeration may be used in this way for studying various types of sub-sampling (see below) of the units; data from a complete enumeration may also be used by regrouping the recording units into different sampling units. Of course, this use is limited by the types of 'molecule' that can be constructed from the

[1] Indeed, a systematic sample (see below) might be regarded either as an assembly of sampling units at equal intervals or as a single complex unit of many parts; the second, though the less usual point of view, may help to make clear why the precision of such a sample cannot be assessed directly from its component parts.

[2] Strictly speaking, totals for specified groupings of units would suffice, but this is unlikely to offer any practical advantage.

available 'atoms', and a complete enumeration in small recording units is especially valuable because of the wide variety of potential sampling units that can be examined.

The controversy between advocates of random and of systematic sampling has been in progress for many years, and is an important issue in modern forest sampling. Comparison of the two will form the chief subject of the remaining sections and of a later paper.

Unrestricted random sampling is in principle the simplest type of sampling, and others cannot properly be understood except by reference to it. A *random sample* is one for which selection of each sampling unit composing it is made at random, independently of the other sampling units. It cannot be too strongly emphasized that when the statistician speaks of *random selection*, he refers to a genuinely random process using a table of random numbers, unbiased drawings of cards from a well-shuffled pack, throwings of a well-balanced coin or die, or some equivalent action. He does not include the systematic selection obtained by listing all sampling units and then, for a 5 per cent. sample say, taking every twentieth from the list. Of course, if the order of listing were itself strictly random, such a procedure would give a truly random sample, and in some circumstances, as for example in sampling from an alphabetical list of names, the order may reasonably be assumed random with respect to the quality studied. In the sampling of an area of land, however, the order of successive sampling or recording units will not be random in respect of either soil or vegetation, and, whatever virtues there may be in the choice of regularly spaced units, the resulting sample cannot be regarded as random. Nor may 'haphazard' selection be considered random; experience has shown that haphazard procedures such as casting a hoop into a crop of standing wheat or thinking 'at random' of the reference numbers of sampling units, however honestly conceived and carried out, are liable to introduce serious biases [Yates, 1935 (24)]. The randomness of a sample is a property not of the particular set of sampling units comprising it but of the sequence of operations by which these were selected from the total.

An *unrestricted random sample* is one for which 'selection from the whole population of sampling units into which the material is divided is made by some strictly random process, such as numbering all the units and selecting the requisite number of numbers at random by drawing lots or by the aid of a table of random numbers' [Yates, 1946 (26)]. For example, if the sampling unit is to be an acre, 5 chains $\times$ 2 chains, the 10,000 acres may be divided into 500 rows of 20 units each. A 5 per cent. unrestricted random sample would consist of 500 units, each selected randomly and independently of all the others; such a sample might be constructed by numbering the units from 0000 to 9999 and selecting 500 different four-digit reference numbers by means of a table of random numbers [Fisher and Yates, 1947 (5); Kendall and Babington Smith, 1939 (18)]. Every possible set of 500 units would have the same chance of being chosen for the sample. In practice, this simple scheme is seldom adopted because of the risk that a large region of the stand might fail to be represented in the sample, or that another region might have excessive representation. More useful, because it prevents

the occurrence of a very uneven distribution of sampling units, is some form of *restricted* or *stratified random sample*. The whole area is first divided into a number of *strata* or *blocks* (see section 8), and the sample consists of sampling units taken from each block in proportion to its size. Often the blocks are all of the same size, but this is not essential; for a 5 per cent. sample, 5 per cent. of the units in each block will be selected, irrespective of block size. The units from each block are selected at random, and are in fact an unrestricted random sample from all the units of the block. For example, again with a 5 per cent. sampling fraction, the 10,000 acres might be divided into 100 blocks of 100 chains × 10 chains, each containing 100 of the 1-acre sampling units; within each block 5 units would be chosen entirely at random in order to make up the total of 500. Alternatively, the area might be divided into 250 blocks, each consisting of a double row of 20 units across the area, and 2 units would be chosen randomly from the 40 of each block. Another arrangement would be 500 blocks, each a single row of 20 units, and 1 unit chosen randomly from each block. Stratified random samples are in some respects analogous to the 'randomized block designs' so frequently used in field experimentation.

In the last paragraph a condition has been imposed that the same fraction of the total number of units in each block shall be taken for the sample. Neyman [1934 (21)] and Yates [1946 (26)] have pointed out that the precision of the final estimate will be improved if the more variable blocks are sampled more intensively and the less variable correspondingly less intensively. The estimate must then be formed, not simply from the average for the whole sample, but by first estimating means for each block and then combining these in proportion to the block sizes. In forest sampling, however, prior information on differences between blocks in respect of their variability will rarely be available, so that little use can be made of this sampling with a *variable sampling fraction*. Mahalanobis [1944 (19)] has discussed sample survey methods in great detail, and with special reference to the efficiency of utilization of time and labour, as expressed by his 'cost function'; the gain in efficiency that he effects by suitable distribution of sampling units is primarily a result of using a variable sampling fraction. Yates has observed that even a very rough adjustment to sampling fractions may greatly improve precision when blocks differ widely in variability, and advantage should be taken of this whenever any knowledge of variability within blocks enables a variable sampling fraction to be used. This technique will not be discussed fully here. The slight, unavoidable variations of sampling fraction from one block to another that occur in forest sampling, because irregular boundaries cause the sizes and shapes of blocks to deviate from the ideal, need not be considered as introducing this complication, though care should be taken to avoid bias from this source in the estimation of total volume (section 5).

A *systematic sample* is one for which the positions of all sampling units relative to one another are determined in advance according to a pattern and without recourse to random selection. Most usually, the pattern is a regular spacing of units. For example, with the 1-acre sampling unit as before, selection of every fourth unit in every fifth row would give a systematic 5 per cent. sample of the

stand. This particular type of configuration of units is often described as a *grid sample*, since the units lie at the corners of a 4×5 grid placed on the area. The position of every unit in the sample is determined when that of the first has been decided. Two sub-types of systematic sample may be distinguished, the position of the first sampling unit being decided in the one by a fixed arbitrary rule, in the other by random selection from the set of possible positions.

Random and systematic samples are forms of *objective sample*. The constituent sampling units are selected according to rules which may or may not include the operation of chance but cannot be affected by personal opinions as to which units are truly 'representative' of the stand. Any sample which selects areas of the stand for inclusion in the sample according to whether or not they appear to an observer as representative may be classed as a *subjective sample*.

In some types of forest, and especially in tropical forest with dense undergrowth, the location and enumeration of isolated small sampling units would be excessively costly: since a path would have to be cut to each unit from a distant base line, the expense of the enumeration itself might be small in comparison with that of path cutting. A more satisfactory sampling unit in these circumstances is a narrow strip, at right angles to a base line and running completely across the forest. Such a unit might be considerably larger than those previously discussed, but, in view of the difficulties of path cutting, the cost per unit would not be proportional to its size. The intensity of sampling needed in order to attain satisfactory precision would probably be greater than for small units (section 9), but the total number of units, an important factor in determining cost, would be less.

This form of sampling, *strip sampling*,[1] may be random or systematic. If a strip 2 chains wide across the 10,000-acre stand is chosen as sampling unit, each unit would be 20 acres in area and the whole stand would contain 500 units. A 10 per cent. unrestricted random sample would require the selection of 50 strips by some fully random process. Stratification might be introduced by regarding 10 successive groups of 50 strips as forming 10 blocks, and selecting 5 strips at random from each 50, or by regarding 25 successive groups of 20 strips as the blocks and selecting 2 strips from each. A 10 per cent. systematic sample would generally be chosen to consist of every tenth strip; the first strip of the sample might be defined arbitrarily as, say, the fifth of the 500 or alternatively selected at random as one of the first 10. The condition for a systematic sample is merely that the separate units should be spaced according to some predetermined pattern, and not necessarily that they should be spaced with perfect regularity: a 10 per cent. sample chosen to consist of strips numbered 7, 13, 27, 33, 47, . . . , 493 would be systematic. Complete regularity, however, is the most usual and the most useful type.

In this section only a brief outline of the various principles that may be adopted in the selection of a sample has been given. Further modifications and

[1] Strip sampling has sometimes been termed 'line sampling' [Matérn, 1947 (20)], but in view of the importance of ensuring that a constant width be enumerated, in order to eliminate bias, it seems advisable to emphasize the strip rather than the line.

extensions have been devised and possess advantages in some circumstances, as giving a result of specified precision for a lesser expenditure. One of these is *sub-sampling*, the division of each primary sampling unit into smaller sub-sampling units; sampling then proceeds in two stages, first the selection of primary units and secondly the sampling of each selected unit by means of the sub-units. Methods of *double sampling*, in which a second quantity, which should be highly correlated with volume (or any other main subject of investigation), is measured for each unit, deserve further study and exploitation. The concomitant variate is used as a control upon variation in the first, either with the aid of a regression equation or in a balanced or purposive selection of the sample. These more elaborate methods, however, though potentially valuable, fall beyond the scope of the present paper. The statistical technique has been discussed by Cochran [1942 (3)], Neyman [1934 (21)], Schumacher and Chapman [1942 (22)], and Yates [1946 (26)].

5. BIAS IN ESTIMATION.

An estimate is said to be *biased* if repetition of the procedure by which it was derived, including fresh randomizations at any stage where the instructions call for a random selection, would give results which, when averaged over an extended series of repetitions, differ from the true value of the quantity estimated. A complete enumeration is, by its very nature, unbiased, for its result is the true value, and repetition of the enumeration would always give the same value (if mistakes of measurement are considered negligible in effect). A sample enumeration cannot be guaranteed to give the true value, and, except by rare chance, will not do so; in practice, the magnitude of its error will not be known, but a condition may be imposed that the sampling procedure shall be such as would give the correct result as an average if it were repeated indefinitely. The repetition is conceptual, not actual, but the idea of generating a large number of estimates by repetition of the sampling process is fundamental to the study of bias and of the assessment of sampling error.

'The ideal which is aimed at in sampling is to make the sample as representative as possible, so that measurements and observations on it can be taken as virtually equivalent to similar measurements on the whole population. The fact that this ideal is in the mind of the sampler when taking the sample naturally influences his selection if he has any freedom of choice. Most samplers when selecting a representative of the abnormal as well as the normal will deliberately balance up the different categories of abnormality. Unfortunately the sampler's claims to be able to select "a representative sample" by personal judgement are largely unfounded, and his selection is in fact subject to all sorts of biases, psychological and physical. To avoid these biases . . . more rigorous processes of selection have been devised' [Yates, 1935 (24)].

Yates then states that 'If bias is to be avoided, the selection of the samples must be determined by some process uninfluenced by the qualities of the objects sampled and free from any element of choice on the part of the observer'. The only sure way of avoiding bias is to introduce a proper degree of randomization into the selection of the sample. An unrestricted random sample must be unbiased, for every possible selection of the specified number of sampling units

has the same probability of being the one chosen, and repetition of the sampling would ensure that, in the long run, all occurred equally often. A stratified random sample will be unbiased if the number of units from every block is the same proportion (the sampling fraction) of the total number in the block. Departure from this proportionality, either because a constant fraction would require non-integral numbers of units from some blocks or because the sampling fraction is deliberately varied, has the result that certain blocks are represented more fully than others. An estimate formed by simple averaging of all units in the sample would therefore be biased. Adjustment may be made easily, however, by using the units sampled in any block to give an estimate of the mean for that block and then deriving an unbiased estimate of total volume by multiplication of each block mean by the total number of units in the block. If variations in the sampling fraction are due only to slight variations in block-size resulting from irregularity of the forest boundary, the bias in using an estimate based on the simple arithmetic mean of units in the sample should be small, but its elimination should always be effected unless arithmetical investigation for a particular investigation shows it to be negligible.

A systematic strip sample which by rule began with, say, the fifth strip of the stand would be biased, according to the strict definition that has been given, since repetition would always give the same sample and the mean volume for this would not in general coincide with the mean for the stand. Such a sample is objective, however, and over a series of samplings of different stands the bias might be expected to average out: the estimate is biased in respect of the one stand, but may possibly be regarded as unbiased in relation to a large number of stands, all of which are to be sampled according to the same rule. On the other hand, the sample persistently avoids strips at one edge of the stand, and these may tend consistently to carry lesser (or greater) volumes than strips in the middle. Bias from this source would be negligible in very large stands, but whether it exists or is important in ordinary sampling practice cannot be told without the collation of evidence from many stands. Random selection of the first strip of the sample will eliminate most of the bias, though, unless the total area is an exact integral multiple of the sample area, the estimates from the possible samples will not quite average to the true value. As a simple example, consider a 10 per cent. sample of 33 strips. Of the 10 samples, equally probable when the first strip is selected at random from numbers 1 to 10, 3 will contain 4 units and 7 will contain 3 units; the average of the 10 possible estimates will therefore differ from the true arithmetic mean of the 33 strips. Such an effect will scarcely be important, however, in large stands.

Subjectively selected samples may easily be very seriously biased, however honest the intention of the investigator, and, for this reason if for no other, they should never be employed except perhaps in preliminary rough surveys. Yates [1935 (24)] and Cochran and Watson [1936 (1)] have given examples of the large and unpredictable biases that may occur when even the most honest observers use their own judgement to choose representative samples. Evaluation of the personal equation of each of a set of observers would scarcely be practicable, even

if the result could be regarded as providing a trustworthy adjustment to future estimations. Objectivity of selection, therefore, is a prerequisite of any reputable sampling scheme.

The discussion of bias has so far concerned bias inherent in the sampling technique adopted. Bias may also result from failure to adhere strictly to sampling instructions or failure to make these instructions sufficiently well defined. Discussion of the precautions to be taken in the demarcation and enumeration of a sampling or recording unit in order to avoid bias falls outside the scope of this paper. Nevertheless, the importance of establishing strict conventions in order to ensure objectivity may be emphasized. The writer does not know of numerical evidence of bias arising from the intrusion of the personal element into forest sampling, but the lack of evidence is probably a consequence of lack of investigation rather than absence of danger. Experience in the closely related problem of field-crop sampling has shown that failure to insist on sampling units being located strictly according to an objective procedure may allow the observer subconsciously to act on a preference for high yields. Yates [1935 (24)] has given examples of this phenomenon. If, for example, a random selection decides that a sampling unit shall be taken with one end 115 yards from a base line, chance deviation from this figure by a few yards may matter little; what is important is that the observer should fix the end absolutely at an objectively measured mark, and should not permit himself a few feet variation either way for 'convenience' (and incidentally for the unconscious introduction of bias!).

In a complete enumeration, exact measurement of the areas of recording units and decisions as to whether certain marginal trees shall be taken as inside or outside the unit may be unimportant, since every tree will be recorded once, and once only, in the enumeration. In a sample enumeration any bias in the measurement of units and any tendency to include or exclude more than the right proportion of marginal trees may lead to serious over- or under-estimation of volume per unit area. Careful measurement of units and an unbiased rule for marginal trees are particularly important when the sampling unit is small. Marginal trees might be included if, and only if, more than half their cross-section is within the recording unit; an alternative and perhaps more easily operated rule would be to include all trees on the north and west margins, and to exclude all trees on the south and east margins, irrespective of how much of any one tree lies within the unit. Sukhatme [1947 (23)], as a result of extensive trials, has found the over-estimation of wheat and rice yields to increase markedly when the sampling unit is made small. Clearly this should not happen if no more than the crop within the unit is taken for the sample, and that it does happen in carefully conducted investigations shows how difficult the elimination of the human factor can be. In forest sampling the units are much larger than Sukhatme's few square yards, but bias of a similar kind could easily occur.

6. PRECISION OF ESTIMATION.

As is usual in discussions of the statistics of sampling, the word *precision* will be restricted to the sense of the reproducibility of an estimate in repeated

sampling. A sampling estimate might be seriously biased, yet would still be described as of high precision if repetition of the sampling procedure would always give almost the same value. Again, an estimate might be free from bias, yet of very low precision; for example, an estimate of the volume for 10,000 acres based upon a randomly selected single acre would be unbiased, but repetition of the sampling would probably show that the result was far from reproducible. Once again the concept of infinite repetition of the sampling procedure is essential to the definition.

This exact usage of 'precision' must not be confused with 'accuracy' in the sense of approach to the true value. The popular idea of accuracy seems to include both freedom from bias and precision, that is to say both an average result which will be the true value and little dispersion of individual samples about that average. For scientific purposes, separate treatment of these two topics is necessary, as the factors governing them are quite different; avoidance of the word accuracy in this connexion therefore seems desirable, and instead it may be used, if required, as indicative of correctness of measurement of constituent items of the sample and arithmetical correctness of associated calculations.

Unrestricted and stratified random samples lead to unbiased estimates, providing that results for the latter are suitably adjusted for variation in the sampling fraction. Stratification, however, will generally tend to increase the precision for a specified intensity of sampling, since it prevents the occurrence of some of the more extreme selections of sampling units in which certain parts of the stand receive very unfair representation. The precision of systematic samples is a subject of controversy, about which more will be said in section 9.

As a numerical measure of precision, it is customary to use the *invariance*, the reciprocal of the variance of the estimate (i.e. the reciprocal of the square of the standard error of estimation). That the quantity behaves in the manner naturally required of a measure of precision, increasing as the reproducibility of estimates in repeated sampling improves, is apparent, but justification for the choice of this particular measure must be sought in standard works on statistical theory.

7. SIZE AND SHAPE OF SAMPLING UNITS.

Neither the size nor the shape of the sampling unit for any particular survey can be decided entirely from statistical considerations, for practical convenience must also be taken into account. Nevertheless, the guidance of general statistical principles and the evidence of past experience are of great importance in the choice of unit. Only rectangular and square units will be discussed here (the shape of units at the edge of a stand with an irregular boundary may be disturbed a little without seriously affecting the statistical analysis). In the sampling of agricultural crops, circular or triangular units possess some advantages in view of the ease of marking them, but they are unlikely to be widely adopted in forestry. The general argument of the next paragraph, however, is applicable to any shape.

For a fixed intensity of sampling, use of many small units will permit a better distribution over the whole of the forest area than a few large units, and will therefore tend to give better representation of the stand and a more precise

estimate of volume, unless the spatial distribution of volume is entirely random. If the cost of taking a sample were dependent only on its size (that is to say, on the intensity of sampling), the best policy would be to use the smallest practicable size for the sampling units; in fact, the cost will increase to some extent with increase in the number of units to be enumerated, even when the sample is fixed in size, and the most economical unit can therefore be decided only on the basis of past experience and estimation of costs. The possibility of bias resulting from the use of very small units has already been mentioned [Sukhatme, 1947 (23)]. The size of the recording unit, it should be noted, may be chosen entirely according to convenience, except in so far as a small recording unit might lead to bias in the sampling units.

If the volume per unit area has a tendency to vary in one direction much more than in a direction at right angles, because of a fertility gradient or some similar cause, long narrow sampling units, running parallel to this direction, will generally lead to greater precision than square units of equal area. The variation between units will be reduced by the tendency of each unit to cut across regions of high and low yield. Unless there is advance information on a fertility gradient, or at least indications of probable variations in volume associated with the topography, square units are perhaps the best choice. When the nature of the forest necessitates adoption of strip sampling, the sampling unit will generally be larger than is customary for other types. The unit must then be long and narrow, and the base line should therefore be chosen at right angles to any direction in which a marked trend is expected. The argument of the last paragraph suggests the use of many narrow strips rather than a few wide ones, but again the purely statistical concept of precision must be considered in relation to the economics of sampling.

Examination of past records for the information they give on the optimal size for a sampling unit usually involves analysis appropriate to each of several sizes of unit that may be constructed from the recording units used. In this way, the expected precision of different sampling schemes, with and without stratification, may be assessed, and compared with assessments of costs for the schemes. Assuming that bias has been eliminated, that sampling unit and system of stratification which for a particular stand gave maximum precision for a specified cost (or minimum cost for a specified precision) would be regarded as optimal for the stand. Comparison of similar stands might then indicate that one procedure was optimal, or near optimal, for all, and this might then be recommended for future use with further similar stands. Examples of this procedure have frequently been published in many fields of application of sampling, and Yates and Zacopanay [1935 (27)] have given a particularly full discussion. An important point, often overlooked by the non-statistician, is that, from analysis of any random sampling records comprising at least two sampling units per block, the precision of an estimate based on any other intensity of sampling and using the same system of stratification may be predicted. When a complete enumeration is available, a single analysis of variance can be made to yield predictions of precision for an estimate obtained by any intensity of sampling

in a given system of stratification, and this is always more trustworthy than the common procedure of constructing one or two specimen samples from the enumeration.

When the area to be sampled is roughly rectangular, the axes of the rectangle will naturally be taken as defining the orientation of rectangular sampling units. In the stand used as an illustrative example for this paper, 1,000 chains × 100 chains, practicability and previous experience will be assumed to restrict further discussion either to sampling units of 5 chains × 2 chains (1 acre) or to strips across the rectangle and 2 chains in width (20 acres).

8. SIZE AND SHAPE OF BLOCKS.

The main purpose of stratification is the segregation of parts of the stand which differ widely in their mean volume per unit area. The region within a block should be as homogeneous as possible. In the absence of previous information on the character of the area, blocks would naturally be planned as compact subdivisions of the stand, but advantage should be taken of any previous knowledge of fertility, or of topographical features that may serve to indicate variations in volume, in planning for within-block homogeneity. Ideally, all blocks would have the same shape, but in practice some variation must be permitted.

The smaller the blocks, the less likely is each to be heterogeneous. Consequently, for a given intensity of sampling and size of sampling unit, the precision is likely to be highest when the number of blocks is as large as possible. An absolute limit is set by the restriction that at least one sampling unit must be taken from each block. If the sampling is also to provide an assessment of the standard error of the volume estimate, the number of blocks must be such that at least two units are taken from each (section 9). In strip sampling, the choice of block size and shape is much restricted, but the aim of reducing the size so that only two sampling units (only one if no assessment of error is required) are needed from each should be kept in mind. Of course, statistical theory is in no way invalidated by use of more than two units per block; larger blocks and more units per block are permissible and are sometimes more convenient.

9. RANDOM AND SYSTEMATIC SAMPLING.

The precision of an estimate derived from a random sample, whether stratified or not, may be assessed from the variation between independently selected sampling units. The standard statistical processes by which the assessment is made, which usually take the form known as 'analysis of variance' [Cochran, 1939 (2)], need not be described here; it is sufficient to note that independently selected units (and these only) give information on the variability that might occur in repeated sampling. In an unrestricted random sample, the calculations use the differences between all the units of the sample. In a stratified random sample, a component representing variation between blocks must be subtracted from the total, as only variation within blocks is relevant to the precision of the

estimate. The reason for choosing small, homogeneous blocks is to make the residual, or within-block, variation small.

A clear distinction must be drawn between the 'true' precision of an estimate and an assessment of it calculated from the internal evidence of a single sample. The distinction is similar to that between the true figure for the total volume and the sample estimate of that volume: both true values always exist, but neither can be derived exactly from a sample. Providing that the sample includes at least two sampling units per block, the calculations for obtaining a sum of squares 'within blocks' can always be carried out, and so an assessment of precision can be made. If only one sampling unit in each block is enumerated, no 'variation between independently selected sampling units' within blocks can be measured, and therefore no assessment of precision is possible. On the other hand, if a sampling scheme using blocks in each of which $2k$ units are to be enumerated be modified so that the blocks are divided in half and k units taken from each, variation between half-blocks will be eliminated and, according to the general principle already stated, an increase in precision will be expected. In particular, putting $k = 1$, if a scheme requiring two units per block be modified so as to have one unit per half-block, the true precision of the estimate of total volume is likely to be increased, though the sample no longer provides data from which that precision may be assessed.

Consequently, if a random sample of a forest is required to furnish its own estimate of error, the smallest permissible block size for any specified intensity of sampling will be such that two sampling units are taken from each block. If the estimate of error is not required, division of each of these blocks into half may be desirable, as some increase in true precision is then to be expected for the same size of sample. For a scheme having only one enumerated sampling unit per block, not only can the precision not be assessed, but also *no estimate can be formed of what the precision would have been if blocks of twice the size and two units per block had been used.* An upper limit to the sampling error of the volume estimate (i.e. a lower limit to the precision) may be formed from a sum of squares between sampling units within pairs of neighbouring blocks. This, however, is likely to be of least use in just the circumstances for which small blocks are most effective, since the extent to which it over-estimates the error will depend upon the degree of heterogeneity between blocks relative to the (unknown) variation within blocks. Nevertheless, when experience enables a block size and intensity of sampling with two units per block to be chosen with fair assurance that an estimate of adequate precision will result, there may be justification sometimes for seeking still higher precision, while sacrificing its measurement, by further stratification into half-blocks.

So far this section has been concerned only with random samples. If the volumes of timber on individual sampling units of the forest were distributed entirely at random, so that figures for adjacent units were completely independent of one another, any objectively selected sample would be equivalent to an unrestricted random sample; such a sample would necessarily give an unbiased estimate of total volume, and the precision of the estimate would be dependent

only on the size of the sample. If the distribution were not entirely random, but a system of blocks could be demarcated, which might differ in respect of mean volume per unit area though within any one of them volumes on individual units were randomly distributed, then any objective sample which required enumeration of the same proportion of every block would be equivalent to the corresponding stratified random sample. In either case, the random arrangement is supposed to be a natural property of the forest, so that further randomization by the investigator would be unnecessary. These conditions may not be realized in practice. Indeed, one of the chief reasons for the frequent advocacy of systematic sampling, rather than random, is that forests are expected to show systematic trends in volumes on neighbouring sampling units within any set of blocks.[1]

As is well known to all who have worked with randomly selected sampling units, by chance these may be so distributed as to leave fairly large regions unrepresented, even though a block restriction prevents the most serious forms of maldistribution; a systematic sample, on the other hand, must consist of units regularly distributed over the whole stand. Consequently, if timber volumes on neighbouring units tend to be correlated to an extent that is not easily removed by stratification, a systematic sample might be expected to be more representative, and therefore to give a more precise estimate, than a random sample of equal size. That this is not necessarily true is easily seen from consideration of an extreme example: if sampling units with high and low volume follow one another according to some periodic pattern, a systematic sample may be much less precise than a random. Suppose that, apart from minor fluctuations, the volumes on the 500 strips of the illustrative example vary cyclically with a period of 20; that is to say, each successive set of 20 strips almost repeats the variations of the first set. If a systematic 5 per cent. strip sample is enumerated, using a randomly selected first strip, though the resulting estimate will be unbiased, each of the units will fall in the same position of the cycle (each in a trough, perhaps, or each at a peak). The estimates from the 20 possible samples of this type would vary much more widely than would estimates from random samples using 1 strip randomly selected from each block of 20, or 2 from each block of 40, for the latter would almost always contain units from different parts of the cycle. Of course, this example depends upon the coincidence of the period of variation in volume with the interval between successive systematic units, and even regular periodicity is unlikely to occur in reality. An artificial example, however, is sufficient to demonstrate that a systematic sample is not necessarily the most precise: other patterns of variation might have similar consequences.

[1] Other reasons are that enumeration of a systematic pattern of units generally provides more useful information for the mapping of the stand than would a random sample of the same size, and that the location of sampling units is easier—and mistakes consequently less likely—when these are spaced regularly. Neither of these advantages can be expressed quantitatively. In some circumstances one or other of them may be so important as to override any defects of systematic sampling, in others they may be ignored. Further discussion of them would be out of place here, for the choice must be made by the investigator in relation to the needs of a particular problem.

The possibility of bias in a systematic sample, resulting from avoidance of marginal sampling units, has been mentioned earlier; this is unlikely to be important in a large stand, and the chief danger may be removed by random selection of the first unit. Such random selection may itself have disadvantages, especially if there is a steady trend in volume per unit area from one end of the stand to the other, by reducing the precision, a matter which will be discussed in a later paper. Periodicity, of the kind described above, is a second danger in the use of systematic schemes, also unlikely to be important but also giving no warning of its occurrence when only the evidence of a single sample is available. Apart from these objections, the chief advantage of systematic sampling may be admitted: in general, the estimate is likely to have a standard error smaller than that of an equal-sized random sample, unrestricted or stratified, and the more pronounced the pattern of variation in the forest the greater will be the gain in precision. Just as for random sampling with only one enumerated unit per block, however, the standard error of estimation cannot be assessed from records of the sampling units in a single systematic sample. In a valuable discussion of the theoretical basis of systematic sampling, Yates [1946 (26)] says, 'If a systematic sample has been taken, on the other hand, we cannot, from the internal evidence of the sample itself, determine either the gain in accuracy[1] over a random sample or the actual accuracy[1] of the systematic sample. Nevertheless, an upper limit to the sampling error can always be obtained from the differences of consecutive pairs of systematically located units, but such an estimate, with continuously varying material, may be much above the true value.' Here Yates appears to ignore the possibility of periodicity, which could make his 'upper limit' much *below* the true value. More seriously, perhaps, as for random sampling with one unit per block, the degree of over-estimation by the upper limit will be greatest in the circumstances which make systematic sampling most advantageous, namely, when the pattern of variation between neighbouring sampling units is strongly marked.

In almost every field of application of sampling methods, papers have been published in which their authors claim to have 'proved', from statistical analysis of sampling records, that systematic selection gives lower standard errors than random, at least for their problem. Very frequently the conclusion is based either upon the use of individual sampling units of a systematic sample exactly as if they had been selected according to some random scheme or upon a similar use of recording units. If the timber volumes for all sampling or recording units were randomly distributed over the forest, this would not matter: nature would then have performed the randomization that man despised. When an investigator adopts systematic sampling primarily because he believes the spatial distribution of volumes to be systematic, however, he cannot consistently analyse his results by a method which ignores this.

Sometimes the plea is made that random selection might have given exactly the same set of sampling units as those in a systematic sample. So it might, but this is no justification for ignoring the method of selection actually used. The

[1] Here used for 'precision'.

procedure adopted in the selection of a sample always determines whether the data can provide an assessment of the precision of the volume estimate, and, if they can, how that assessment shall be derived. Statements of standard errors of sampling, and of probabilities of deviations of an estimate from the true mean, refer not merely to the unique sample enumerated but to that sample in relation to all others that could occur in repeated application of the sampling procedure. In particular, the calculations for the standard error must depend upon the element of random selection present in the selection of the sampling units, and must take account of any stratificatory or systematic restrictions. The information provided by one random sample on the totality of possible random samples is quite different from the information provided by one systematic sample on the totality of possible systematic samples, even though both chance to consist of the same sampling units.

The fault of treating recording units as though they were sampling units, and assessing precision from the variation amongst them, is often found associated with that of treating a systematic sample as random. Both unfortunately mar otherwise excellent studies of the statistical background of forest sampling, such as the series of papers by Griffith [1945, 1946 (6) to (15)]. That a single sampling unit, whether randomly or systematically selected, has been enumerated in several parts is no reason for using the records of these parts as though they related to independently selected sampling units; the extent to which a sampling unit is representative of the stand cannot be affected by the number of subdivisions used in enumerating it. These mistakes in the analysis of sampling records are typical of one of the most dangerous pitfalls of statistical science for the unwary. The computations required in a statistical analysis are generally very easy; they may be intricate or tedious, but they seldom require more than extensive application of the rules of elementary arithmetic. The logical basis of the computations and the reasons for adopting them in a particular problem are much less easily understood. The fact that a well-known scheme of computations could be performed on certain data is no guarantee that it is logically appropriate and will lead to valid conclusions!

The exact sense of the statement that the standard error for a systematic sample cannot be assessed needs to be clearly appreciated. If data for a complete enumeration of all sampling units of a stand are available, the sampling errors for various types of sample, systematic or random, may be calculated; this is too late to be of any use for the stand itself, though it may be of value in suggesting the precision likely to be obtained in the sampling of similar stands. The virtue of random sampling with two or more sampling units per block is that an unbiased estimate of sampling error can be calculated from records of individual sampling units without any hypothesis as to the mathematical form of the frequency distribution of the errors of these units. An assumption that this error distribution is approximately of the form known to statisticians as *normal* enables fiducial limits to the volume estimate to be specified, between which the true volume is very likely to lie; it is well known that even apparently large departures from normality of the error distribution for individual sampling units

are of little importance when the volume estimate is based on the mean of a large number. For a systematic sample, the naïve assumption that a sampling error may be calculated by regarding the units as randomly selected is at variance with one of the chief reasons for adopting systematic selection. It might give an answer near to the truth, but presumably only in stands for which systematic sampling does not increase the precision; the extent to which it gives misleading results can be judged only after extensive examination of data from complete enumerations. Methods which have been proposed for deriving an assessment of error from a systematic sample involve more elaborate assumptions relating to the distribution of volume per unit area for the sampling units. Cochran [1946 (4)] and Matérn [1947 (20)], for example, have suggested mathematical models which specify the correlations between neighbouring units; only by testing these on different sets of records can their adequacy be judged, and, even if they are found satisfactory, their use might require the estimation from the data of any sample of several additional parameters, so that only samples consisting of many units could give useful results. Empirical methods, dependent perhaps on some modification of the simplest systematic sampling procedure, seem to the writer more likely to be helpful in the near future, and these are mentioned again in section 11.

Hasel [1938 (16)] has stated views on the relative merits of random and systematic sampling in forestry very similar to those given here. For one extensive forest area he finds systematic sampling to give results rather more precise than random, and, remembering the greater convenience of regularly spaced units and their value for mapping purposes, he concludes that in general systematic selection is to be preferred, though some additional sampling units may need enumeration in order to give an indication of precision. His analysis of the problem will be discussed more fully in a later paper; for the present it is sufficient to note that the importance of his conclusions emphasizes the need for the collection and analysis of similar data from other forests in order to broaden the basis of induction.

10. REGULAR PLANTING.

The discussion in preceding sections is applicable with little modification to the sampling of stands in which the trees have been planted at regular intervals. The main principles of sampling and of the comparative merits of random and systematic selection are unaltered. The task of the investigator may be much easier, however, and the restriction to strip sampling may be unnecessary because the location and enumeration of small isolated units is less costly. More regard may then be paid to the desirability of using small sampling units in order to increase the precision of estimates of volume.

Both the sampling unit and the recording unit should have widths which are exact multiples of the distance between rows of trees and lengths which are exact multiples of the distance between trees in a row. Apart from minor variations due to gaps and spacing irregularities, the number of trees in a unit will then be unaffected by its location relative to the rows. If this condition is not observed,

random location of units relative to the rows would result in an additional component of variation, attributable to differences in the number of trees per unit, which would increase relative to the total volume as the size of unit was decreased. On the other hand, though a convention that every unit should be similarly placed in relation to the lines of planting would eliminate this variation, the final estimate might be biased because the number of trees per unit was consistently greater, or consistently less, than the average density of planting required. Even though planting distances are not exactly the same throughout a stand, careful choice of the dimensions of the recording unit in relation to average planting distances may help to reduce variability.

11. RECOMMENDATIONS.

What advice, then, is to be given now? In the first place, sampling rather than complete enumeration seems not merely desirable but unavoidable unless the skilled staff needed for reliable enumeration work are plentiful. A well-planned sample, carefully enumerated, is undoubtedly preferable to a supposedly 'complete' enumeration hastily and carelessly carried out because of the exigencies of time and labour. Sampling must be objective if bias is to be avoided. In a valuable account of the technique of statistical analysis appropriate to forest sampling, Schumacher and Chapman [1942 (22)] state that the investigator who is concerned about the probable discrepancy between his estimate and the true value must restrict himself to random sampling. Strictly, they are correct, though some concession might be made to the situation in which, on the evidence of past experience, a certain type of random sample is thought sure to be sufficiently precise and a systematic sample of equal intensity is chosen as likely to be at least as precise. This argument needs to be used with great discretion! Yates [1946 (26)], on the other hand, says 'Nevertheless, I feel certain that in extensive area surveys systematic line or grid sampling is preferable to random sampling. The additional work required to investigate the accuracy attained will be more than compensated for by the saving in work in the survey itself.' To the writer this statement seems to assume, somewhat prematurely, that a satisfactory assessment of precision can be made. The extent to which systematic sampling saves field work is likely to vary widely according to local organization and conditions, and perhaps need not always be great, though only those with long experience of sampling practice are competent to judge of this.

Yates [1946 (26)] has hinted at the possibility of developing methods giving a reasonably reliable assessment of error for a single systematic sample, by some modification of the sampling procedure. Referring to strip sampling, he suggests, as one possibility, taking 'a second systematic sample which has a slightly different spacing to the original sample, so that information is available on the difference between lines at all spacings'. Another possibility is to obtain information on variability by means of supplementary sampling, random or perhaps systematic, over part of the stand [Hasel, 1938 (16)]. That no satisfactory estimate of error can be derived from a single simple systematic sample seems certain, and the investigator who is determined to have the advantages of convenience and

precision considered to be conferred by systematic sampling must be prepared for some additional labour if he wishes also to assess that precision. Even so, the methods are unlikely to give good results unless the sample consists of a large number (say, at least 100) of sampling units, and only a very large forest would satisfy this condition. If an overall assessment of precision for the total of several stands was sufficient, smaller samples might suffice. Much more work on this matter is needed, however, before any practical recommendations can be made. In particular, suggested methods will need to be tried on samples drawn from complete enumeration data and the estimation of precision compared with its true value; clearly an investigation of this kind is of use only if made on a complete enumeration for which the pattern of variation departs so far from randomness as to give a real advantage to systematic sampling.

Any general advice that may eventually be given must depend in no small degree upon the average increase in true precision resulting from systematic sampling. If this is found to be small, the sacrifice of the estimate of error, or the additional labour involved in obtaining the estimate, unavoidable if random sampling is abandoned, may seem too great a price to pay. Only full statistical analysis of data from many enumerations, with a view to comparing different sampling schemes, can settle this question, and for this purpose complete enumerations in small recording units are of the greatest value. Investigations like those of Hasel [1938 (16)] and Griffith [1945, 1946 (6) to (15)], but with modifications, and corrections in order to take account of considerations such as have been advanced by Yates [1946 (26)] and in this paper, are needed in much greater numbers. The writer hopes to discuss this aspect of the sampling problem more fully in a later paper.

12. SUMMARY.

1. The chief object in the enumeration of a stand of timber is the estimation of the total volume or of the volumes within certain categories. A secondary object is the formation of a numerical assessment of the reliability of the volume estimate.

2. Enumeration data may also be required for mapping the forest, but the optimal conditions for this are not necessarily the same as for volume estimation. The problem of mapping is not discussed in this paper.

3. *A complete enumeration*, by its very nature, gives a value for the total volume which is correct apart from mistakes and faulty measuring by the enumerators. For any large stand it is expensive to carry out and, in the opinion of many, unnecessary.

4. *A sample enumeration* is an enumeration of some portion of the whole stand, undertaken with the intention that its results shall provide an estimate of the total volume. If a satisfactory estimate can be formed from a sample which is only a small proportion of the whole, a great saving will be effected. Whether or not a sampling procedure is satisfactory depends on the degree of agreement with the true value and with one another that would be expected in estimates based on repetitions of the sampling.

5. Understanding of the statistical principles involved is essential to a proper appreciation of the problems of sampling, though a sampling scheme as put into execution will generally involve a compromise between practical convenience and the methods indicated by statistical theory as likely to give the most trustworthy results.

6. The first condition that must be imposed on any sampling estimate is that it shall be unbiased. The selection of sampling units must therefore be entirely objective. Strict rules relating to the location and definition of sampling units and care in all tree measurements are also essential.

7. For a specified intensity of sampling, more precise results may be expected from many small sampling units than from a few large ones. If nothing is known of the nature of variation over the stand, square sampling units are likely to be the best choice; if variation in one direction is believed to be particularly great, long narrow units running parallel to this direction should give higher precision than square units of equal area. Under some conditions, narrow rectangular strips right across the stand may be the only practicable unit, and again the advantage is likely to be with a large number of small units.

8. In a forest which has been planted in regularly spaced rows, the sampling unit should normally have its width an exact multiple of the distance between rows and its length an exact multiple of the planting distance within rows.

9. *An unrestricted random sample*, consisting of sampling units distributed at random over the whole stand, gives an unbiased estimate of the total volume, and also provides data from which the precision of the estimate can be assessed.

10. *A stratified random sample*, in which the distribution of sampling units is subject to certain restrictions, ensures that, on an average, the sample will be more fairly representative of all parts of the stand, and so is likely to improve the precision of the estimate. The estimate, if correctly formed, is still unbiased.

11. In any stratification system the blocks should be chosen to be as homogeneous as possible.

12. For a specified intensity of sampling, small blocks, each contributing few units to the sample, are likely to give greater precision than large blocks of which each contributes many units to the sample. An arrangement such that each block contributes two units to the sample makes good use of this property and permits numerical assessment of the precision from the sample records.

13. A sampling procedure of high precision does not necessarily lead to the collection of data in a single sample from which that precision may be assessed. A system of blocks such that only one sampling unit is enumerated in each may be expected to give a more precise estimate than that from blocks of twice the size and two units per block, but the precision of the former cannot be assessed from the internal evidence of the sample. Nevertheless, choice of such a sampling procedure may sometimes be justifiable.

14. The variations in volume per unit area from one sampling unit to another are often believed to follow a systematic pattern. Stratification to some extent takes this into account by insisting that the sample is widely distributed over the 'pattern' of the stand. Many investigators, however, prefer to take a *systematic*

sample, in which the units selected are spaced regularly over the stand. An additional advantage of such a sample may be easier location of sampling units and so a lesser likelihood of mistakes in the field.

15. If the position of the first unit is selected at random, a systematic sample will give an unbiased estimate of total volume. Without random selection of the first unit, there is some danger of bias, though probably this will be negligible over a series of samplings of different stands.

16. Though a systematic sample may be expected usually to give an estimate more precise than would the corresponding stratified random sample, this is not necessarily true. For some types of variation the precision for the systematic might be the lower, and no general statistical theory can state that one will always be the better.

17. The calculations for the sampling error of a random sample lead to valid conclusions only when the sample is genuinely random, whether stratified or not. Since one important reason for advocating systematic sampling is that variations in volume are believed to show systematic trends, it is neither reasonable nor permissible to analyse the resulting figures as though they referred to randomly selected units.

18. From the internal evidence of a single systematic sample, no assessment of precision is possible without some assumption relating to the variations in volume per unit area in neighbouring sampling units. No advance in pure statistical theory can alter this conclusion, but experience and examination of statistical analyses may eventually indicate certain assumptions as justifiable, at least as approximations. Alternatively, modifications in the usual sampling procedure may assist the formation of some assessment of precision.

19. In no form of sampling can a valid assessment of precision be based on the variance amongst recording units or other subdivisions of sampling units. Records of these, however, may be useful for investigation of the precision that might be obtained with sampling units of other sizes and shapes.

20. Though advice on the conduct of sampling programmes can be based on general statistical principles, evaluation of the relative merits of different schemes can be made only after numerical analysis of actual data. Conclusions will be applicable, strictly, only to the one stand but may also help to build up a body of empirical information on the relative merits. In this connexion, complete enumerations of large stands, recorded in small units, are especially valuable as providing material on which statistical examination and comparison of many different sampling schemes may be tried. Every possible use should be made of existing complete enumeration data in order to increase knowledge of the principles of good forest sampling.

LITERATURE REFERENCES.

(1) Cochran, W. G., and Watson, D. J. (1936): 'An Experiment on Observer's Bias in the Selection of Shoot Heights'. *Empire J. of Experimental Agriculture*, iv. 69–76.

(2) Cochran, W. G. (1939): 'The Use of the Analysis of Variance in Enumeration by Sampling'. *J. Amer. Statist. Assoc.* xxxiv. 492–510.

(3) —— (1942): 'Sampling Theory when the Units are of Unequal Sizes'. Ibid. xxxvii. 199–212.

[4] Cochran, W. G. (1946): 'Relative Accuracy of Systematic and Stratified Random Samples for a Certain Class of Populations'. *Annals of Mathematical Statistics*, xvii. 164–77.

[5] Fisher, R. A., and Yates, F. (1938): *Statistical Tables for Biological, Agricultural and Medical Research*, 3rd ed. Oliver and Boyd, Edinburgh.

[6] Griffith, A. L. (1940 a): *The Efficiency of Enumerations*. I. *The Problem*. Forest Research Institute, Dehra Dun, Indian Forest Leaflet, No. 83.

[7] —— (1940 b): *The Efficiency of Enumerations*. II. *Madras Tropical Wet Evergreen Forest*. III. *Typical Calculations*. Ibid., No. 84.

[8] —— (1940 c): *The Efficiency of Enumerations*. IV. *Madras Moist Mixed Deciduous Forest*. Ibid., No. 85.

[9] —— (1940 d): *The Efficiency of Enumerations*. V. *Upper Assam Tropical Evergreen Forest*. VI. *Typical Calculations*. Ibid., No. 86.

[10] —— (1940 e): *The Efficiency of Enumerations*. VII. *The Distribution of the Volume Figures*. Ibid., No. 87.

[11] —— (1940 f): *The Efficiency of Enumerations*. VIII. *Chir* (*Pinus longifolia*) *Forest in the Punjab and United Provinces*. Ibid., No. 88.

[12] —— (1940 g): *The Efficiency of Enumerations*. IX. *The Distribution of the Volume Figures* (contd.). Ibid., No. 89.

[13] —— (1940 h): *The Efficiency of Enumerations*. X. *Hill Sal* (*Shorea robusta*) *Forest in the United Provinces*. Ibid., No. 90.

[14] —— (1940 i): *The Efficiency of Enumerations*. XI. *The Distribution of the Volume Figures* (contd.). Ibid., No. 91.

[15] —— (1940 j): *The Efficiency of Enumerations*. XII. *One Species in a Mixed Forest* (*Teak in a Madras Moist Deciduous Forest*). XIII. *Conformation of the Chir* (*Pinus longifolia*) *and Sal* (*Shorea robusta*) *Data*. XIV. *Summary of Indications*. Ibid., No. 93.

[16] Hasel, A. A. (1938): 'Sampling Error in Timber Surveys'. *J. Agric. Res.* lvii. 713–36.

[17] Ilvessalo, Y. (1928): 'Suomen metsävarat ja metsien tila' ('The Forest Resources and the Condition of the Forests of Finland'). *Communicationes Instituti Forestalis Fenniae*, xxx. 1–446.

[18] Kendall, M. G., and Babington Smith, B. (1939): *Tables of Random Sampling Numbers*. Tracts for Computers, No. 24. Cambridge University Press.

[19] Mahalanobis, P. C. (1944): 'On Large Scale Sample Surveys'. *Phil. Trans. Roy. Soc. Lond.*, B ccxxxi. 329–451.

[20] Matern, B. (1947): 'Metoder att uppskatta noggrannheten vid linje- och provytetaxering' ('Methods of Estimating the Accuracy of Line and Sample Plot Surveys'). *Medd. frdn Statens Skogsforskningsanstalt*, xxxvi, No. 1.

[21] Neyman, J. S. (1934): 'On the Two Different Aspects of the Representative Method: The Method of Stratified Sampling and the Method of Purposive Selection'. *J. Roy. Statist. Soc.* xcvii. 558–625.

[22] Schumacher, F. X., and Chapman, R. A. (1942): *Sampling Methods in Forestry and Range Management*. Duke University Press, Durham, N. Carolina.

[23] Sukhatme, P. V. (1947): 'The Problem of Plot Size in Large-scale Yield Surveys'. *J. Amer. Statist. Assoc.* xlii. 297–310.

[24] Yates, F. (1935): 'Some Examples of Biased Sampling'. *Ann. Eugen., Lond.* vi. 202–13.

[25] —— (1946): 'Methods and Purposes of Agricultural Surveys'. *J. Royal Society of Arts*, xcv. 367–79.

[26] —— (1946): 'A Review of Recent Statistical Developments in Sampling and Sampling Surveys'. *J. Roy. Statist. Soc.* cix. 12–43.

[27] —— and Zacopany, I. (1935): 'The Estimation of the Efficiency of Sampling, with Special Reference to Sampling for Yield in Cereal Experiments'. *J. Agric. Sci.* xxv. 545–77.

BEHAVIOUR OF CORSICAN PINE STOCK FOLLOWING DIFFERENT NURSERY TREATMENTS

(*Pinus nigra* var. *calabrica* Schneid.)

By M. C. Rayner

INTRODUCTORY.

DURING last winter the writer chanced to meet in the West Indies an officer of the U.S. Forest Service. Discussing the fate of pine and spruce seedlings raised in the nurseries under his control in a Middle West state, he deplored the excessive mortality constantly recorded when seedlings of what appeared to be reasonably good quality were planted out on poor soils other than those of forest type. It has fallen to the lot of the writer to make similar observations over a period of many years in Great Britain and elsewhere, and as a botanist to approach the problem of the causes operating to bring about this result rather differently than does the ordinary forester.

Laboratory examination of the root systems of pine, spruce, and allied coniferous species raised in nurseries on many different types of soil makes it clear that diagnosis of the condition of the roots in respect to mycorrhizal development may point to a very different forecast respecting the future prospects of the plants from that based on assessment of the shoots only. Shoot assessment of 1-year (1+0) and 2-year (1+1) nursery seedlings of pine may provide a much too favourable picture, both of the prospects of the plants when transferred to the field and also of the suitability of the nursery soils in which they have been raised and grown.

The lack or deficiency of mycorrhizal equipment so often observed in nursery stock of pine and spruce, with the development of pseudomycorrhizal[1] features that frequently accompanies it, may be due to the absence of the appropriate fungi from the nursery soil. This is rare, since in most new nurseries precautions are now taken at an early stage to introduce these fungi by lining-out seedlings from nurseries elsewhere known or believed to contain the fungi. In the opinion of the writer it is much more commonly due to the presence of soil factors adverse to the growth and activity of mycelium of these fungi and consequently to their functional behaviour as mycorrhiza-formers. The unsatisfactory condition of the host plants follows upon this. Why soil conditions of this kind tend to be prevalent in forest nurseries and how they come about in those which are carefully tended is another story and must be told elsewhere.

If seedlings of pine or spruce possessing root systems defective in respect to mycorrhizal equipment are transferred to forest conditions when removed from the nursery, the impoverished state of the roots is of little permanent importance.

[1] As used in this paper, the term 'pseudomycorrhizal' describes a condition of the roots in which mycorrhizal association is replaced by root-infection by types of soil fungi other than mycorrhiza-formers.

Assuming the existence of normal forest soil characteristics that include the presence of suitable mycorrhiza-forming fungi for the species, an abundant short root system, all of which is mycorrhizal, will develop, following a short period of checked growth. If similar seedlings are destined for the afforestation of poor and infertile soils that have never carried trees, as is often the case, the subsequent history of the plantings may be very different. Mortality after planting is usually excessive, and a proportion—often a large proportion—of the survivors fail to start growth, and pass into a condition of more or less complete 'check', varying in duration.

In spruces (*Picea* spp.) failure of mycorrhizal association is usually accompanied by chlorosis of the needles, noticeable both in the nursery and in plantings, the severity of this symptom varying directly with the condition of the roots in respect to mycorrhizal association, and responding with great delicacy and rapidity to any change for the better in this respect. That this is a starvation symptom directly related to availability of nutrients, and that it may be possible to alleviate it by ensuring the provision of adequate and balanced supplies of nitrogen, phosphate, and potash, without necessarily affecting the mycorrhizal equipment, is not disputed and does not invalidate the present argument. Some degree of heterotrophic nutrition bound up with a mycorrhizal system adequate to ensure it is a normal feature of the metabolism of these plants under natural conditions. That healthy seedlings of pine and spruce can be grown in sand or water cultures, and the method of hydroponics on a relatively large scale applied to the raising of nursery stock, have likewise been fully demonstrated. In a recent paper Mitchell (1) concludes that 'seedlings grown in *properly balanced* nutrient sand cultures are far superior as regards total weight, balance between root and shoot and, to a lesser degree, root development, than the average nursery-grown seedling of the same age'. The application by Mitchell of these conclusions to nursery and field practice cannot be considered in the present communication which is concerned with another aspect of the problem.

The two sets of observations may be reconciled if it is remembered that the hydroponic method (2), favouring ordinary holophytic nutrition, carries with it complete protection from root competition. Heterotrophic nutrition in these plants, in so far as it is imposed by the mycorrhizal habit, has been evolved under the stresses of competitive root activity, possibly varying in degree with the intensity of competition. Lacking mycorrhizas, a different type of root system is produced, abundantly provided with root-hairs, often more profusely supplied with long roots but usually markedly deficient in the short rootlets that normally become mycorrhizas. Root systems of this kind are notably prone to infections by the mycelium of soil fungi other than the true mycorrhiza formers. Such infections are deleterious to healthy growth and often become a serious source of trouble in forest nurseries.

In young seedlings of pine it is less easy to recognize the shoot characters that accompany poor mycorrhizal development, although to the experienced eye these may not be lacking. As in spruces, the defective root systems are markedly deficient in short roots—potential mycorrhizas—and specially prone to root

infections that impair or inhibit growth. It is not proposed to consider further in this paper the structural features observable in these abnormal types of root system. They present characteristic features to those familiar with the subject and require microscopic examination for their certain identification. For some years this aspect of nursery procedure has been the subject of intensive researches, an account of which will shortly be published. Nor does discussion of cultural methods designed to relieve the symptoms described come within the scope of this communication, the main purpose of which is to direct the attention of foresters to the causes believed to be mainly responsible for the high mortality and unsatisfactory growth of transplants under the conditions stated.

PLANTING EXPERIMENT WITH CORSICAN PINE SEEDLINGS OF DIFFERENT NURSERY ORIGINS.

The present article is an account of a planting experiment designed to test the survival and growth behaviour of Corsican pine (*Pinus nigra* var. *calabrica* Schneid.) seedlings of different nursery origins. The site of the plantation is in Wareham Forest, Dorset, an area of poor infertile heathland in southern England, the soil characteristics of which have been very fully described and discussed in a series of papers published in *Forestry* (3, 4, 5, 6, 7).

At an early stage of the Wareham researches it was recommended that in this soil, and others of similar type in which it had been found difficult to establish transplants, better results might be obtained by direct sowings or by raising seedlings in nurseries within the area, using in either case such methods of ameliorating local soil conditions as had proved effective in providing seedlings with root systems normal in respect to mycorrhizal activity. Both methods have been used with success in Wareham Forest. The present account relates to a planting experiment in a poor and especially exposed part of the area, designed to test the survival value and rate of growth over a period of years of Corsican pine seedlings raised locally on heathland treated with compost, as compared with others raised by standard nursery methods in a nursery 20 miles distant.

The site selected was poor *Calluna* heath in an extremely exposed situation. The ground was double-furrow ploughed in 1938 and planted in 1940. The young trees were carefully notch-planted with an ordinary spade at a spacing of 4 feet apart along the furrows. Three treatments were under observation:

B. Two-year (1+1) Corsican pine seedlings raised by sowing in a compost-treated seed-bed on poor *Calluna* heath in Wareham Forest, lined-out for one year in similar soil treated with compost.

D. Two-year (1+1) Corsican pine seedlings raised by standard methods in a Forestry Commission nursery; lined-out for one year in the same nursery.

C. Two-year (1+1) Corsican pine seedlings raised by sowing as in B; lined-out for one year as for D plants.

All treatments were duplicated at planting, one series, B 1, C 1, D 1, receiving 2 oz. per tree of phosphate fertilizer (basic slag) at planting, the other series, B, C, D, being planted direct without soil treatment. The unit for each treat-

ment consisted of 6 rows of plants of approximately 33 plants each, of which 3 rows were planted without soil treatment and 3 rows received phosphate at planting. The plot units were randomized as shown in the diagram (Fig. 1), each treatment thus being quadruplicated in the two series. In all, about 800 plants from each pair of treatments, B and B 1, C and C 1, D and D 1, were under observation, or 2,400 plants in all.

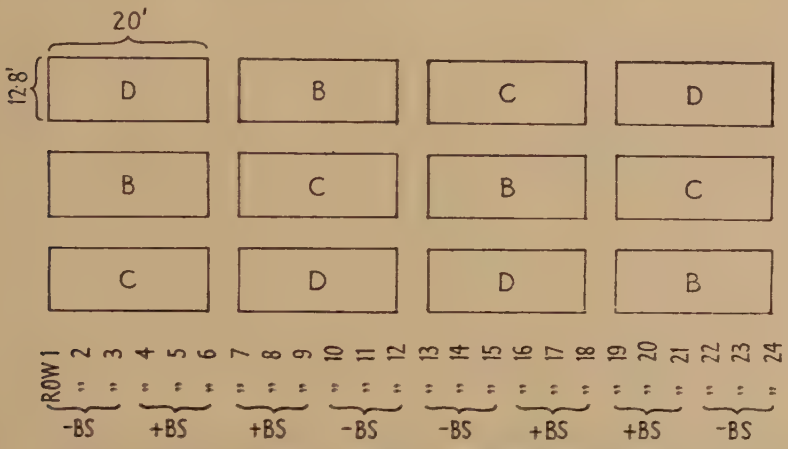


FIG. 1. Layout of experimental plots. B raised in Wareham Forest soil, hop-waste compost; lined-out in Wareham Forest soil, hop-waste compost. C raised in Wareham Forest soil, hop-waste compost; lined-out in 'standard' nursery. D raised in 'standard' nursery; lined-out in 'standard' nursery. Each plot contains 6 rows of 33 plants each; 3 rows in each plot received a phosphate dressing at planting. (To save space, vertical scale approximately one-sixth of horizontal scale.)

The use of compost was dictated by the fact that no other soil treatment has given seedlings of comparable all-round excellence in this Wareham Heath soil (3, 4, 5). The hop-waste compost used was made from fresh hop-waste composted with the addition of dried blood at the rate of 1 per cent. of nitrogen on the dry weight of the basic material. The composting was carried out by a standardized process, and the compost was ready for use 3 to 4 months after making up the heaps. Application to seed-beds and lining-out ground was at the rate of 10 lb. of compost per square yard, at sowing and planting respectively. It may be mentioned that hop-waste compost as used at Wareham is now made without addition of nitrogen, the resulting product giving equally satisfactory effects on growth. Other composts, notably those made from mixtures of bracken and hop-waste, sawdusts and hop-waste, bracken and pine needles, as well as a number of other materials, have given equally good or even better results in nursery practice at Wareham Forest. It is not so easy to summarize briefly just what is meant by 'standard nursery methods', as these inevitably vary somewhat from nursery to nursery. Ordinarily, these nurseries are located on agricultural land, often on old pasture broken for the purpose. Maintenance of fertility is undertaken by various forms of manuring—applications of farmyard manure, leaf-soil from various sources, compost material derived from compost heaps treated as in ordinary garden practice, with additions of phosphate or potash if shortages are indicated.

It is only fair to add that many such nurseries show progressive deterioration of quality in seedlings of pine, spruce, and other trees of similar mycorrhizal habit raised in them.

The reasons for this deterioration need not be discussed here. It is believed that they are likely to be found to be due to the existence of soil factors inimical, sometimes even lethal, to healthy growth and proper functioning of the mycorrhizal fungi associated with the tree species concerned. The presence of these fungi is usually assumed to be ensured by the introduction of seedlings of the various conifers from nurseries elsewhere believed to contain them. Knowledge of their identity depends on the services of a mycologist specializing in work of this kind and is usually deficient or non-existent, while the methods employed to maintain soil fertility often ignore their requirements as distinct from those of their host plants.

ASSESSMENT OF RESULTS.

Assessment of the results of the planting experiment now being described is based on survival and on shoot increments for the current year and total heights of the experimental plants. The photographs reproduced (Plate I) are of representative plants from each series, lifted 2 years after planting. As the scale of these photographs is not sufficiently large to show the remarkable differences still persisting in the root systems in respect to mycorrhizal development, the following comments, abstracted from notes made at the time of photographing, are appended.

B. Stout healthy plant of good colour. Root system well developed and well supplied with mycorrhizas.

B 1. Largest and best plant of series. Root system very well developed, with abundant short roots, all mycorrhizal.

D. Poorest plant of series; colour yellowish. Root system very deficient in short roots. No mycorrhizas.

D 1. Larger and rather better plant than D; colour yellowish. Root system with more short roots, some of which are mycorrhizas.

C. Better plant than D, but far short of B. Root system fair, with some short roots and mycorrhizas.

C 1. Rather better plant than C, with longer needles. Root system with fair number of short roots and mycorrhizas.

The average length of 20 needles taken from the same shoot regions of the experimental plants was as follows: B, 3·5 inches; C, 2·5 inches; D, 1·0 inch; B 1, 4·0 inches; C 1, 3·5 inches; D 1, 2·0 inches.

The following is a note on the general condition of the sample plants at the time of observation, 2 years after planting.

Plants raised and lined-out on heath soil treated with compost are much superior to those raised and lined-out in a standard nursery. The latter are not in any way comparable, whether treated with phosphate at planting or not. In all cases, as might be expected, a supply of phosphate at planting brings about some improvement in root development and shoot growth.

Height measurements made in 1942 on 100 per cent. of the plants are summarized for economy of space in Table I as numbers falling within height groups differing by 5 inches. The comparative values are recorded and displayed in the graphs and histograms reproduced in Fig. 2. If the assumption is made that plants

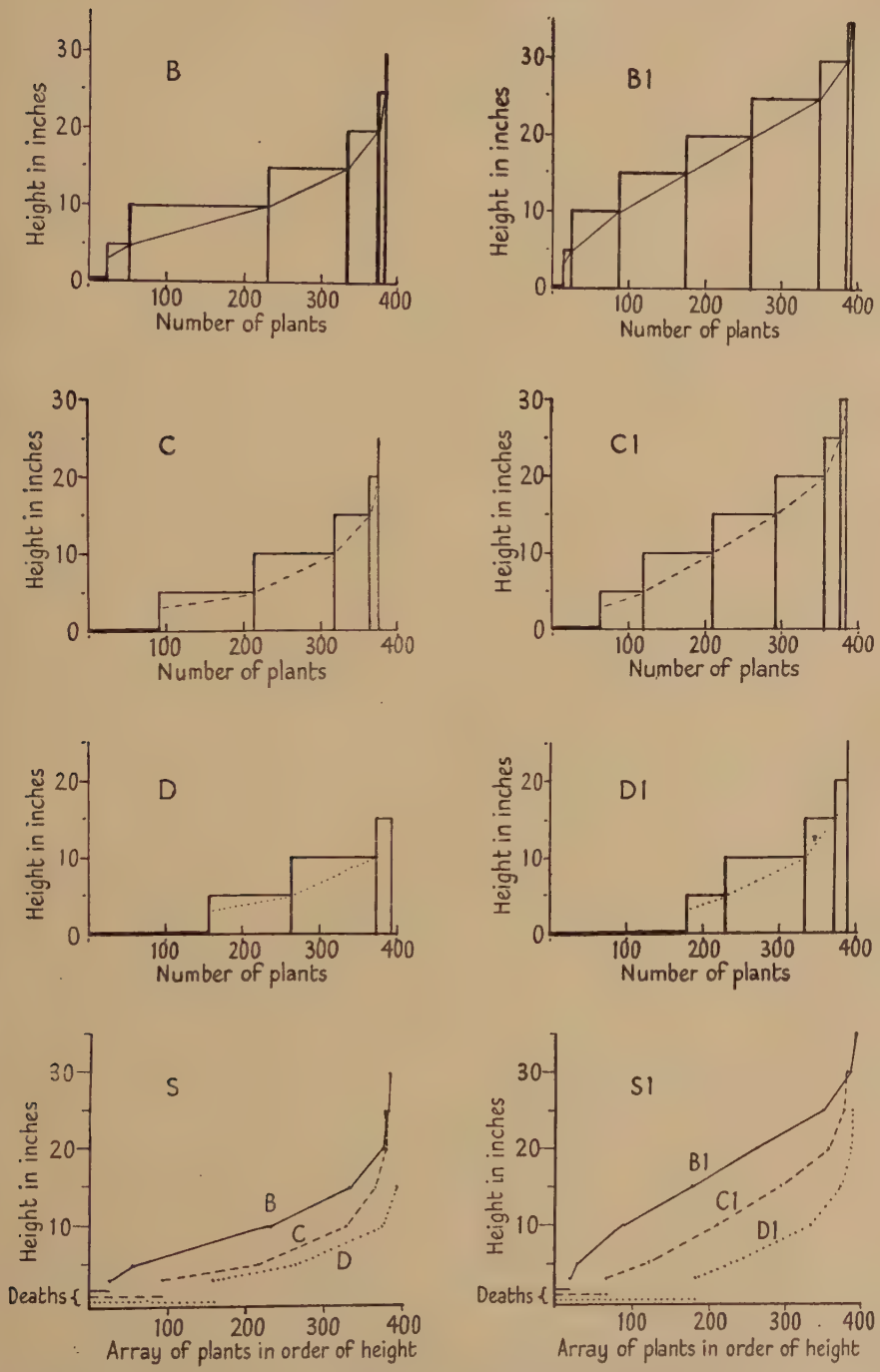


FIG. 2. B, C, D. Numbers of plants falling within height-groups differing by 5 inches, under treatments B, C, and D (see Table 1). B 1, C 1, D 1 received phosphate at planting.

of differing height are distributed evenly within each height group, then the graph formed by joining the right-hand corners of each block represents an array of the included plants in order of height. These graphs form a convenient mode of comparison between the three treatments and are collected together in Fig. 2, S, S 1. The left-hand end of the curve is made to start arbitrarily at 3 inches and not zero, since any plants not dead were at least this height. The number of dead plants is indicated by the horizontal line to the left of the first height-group.

The intermediate position occupied by the C and C 1 plants, both as regards deaths and shoot growth, is at once obvious from the curves.

TABLE I. *Number of plants falling within height-groups differing by 5 inches, under six differing treatments. Sown 1938, planted 1940, recorded 1942*

Height in inches	*B*	*B 1*	*C*	*C 1*	*D*	*D 1*
Dead	24	18	92	65	158	180
0–5	29	9	122	54	104	49
6–10	177	62	115	91	112	104
11–15	102	87	35	84	20	40
16–20	42	85	12	63	..	15
21–25	7	89	1	21	..	1
26–30	2	37	..	7	..	1
31–35	..	4	..	..	..	..
Total number of plants	383	391	377	385	394	390

B, raised Wareham Forest soil+compost; lined-out Wareham Forest soil+compost.
C, raised Wareham Forest soil+compost; lined-out 'standard' nursery.
D, raised 'standard' nursery; lined-out 'standard' nursery.
(B 1, C 1, D 1 received the same treatment as B, C, and D, but were given phosphate at planting.)

In all cases the assessments for mortality, shoot increments, and total height of plants were made in 1941, 1942, 1943, and 1946, 1, 2, 3, and 6 years from planting. Mortality values were obtained by assessment of all experimental plants. The values given for mean shoot increments and for mean total heights in 1941, 1943, and 1946 are mean values based on measurement of 50 per cent. of the plants; those for 1942 were made on 100 per cent. of the plants. Assessments for mortality are given in Table II.

TABLE II. *Percentage deaths after planting*

	B	*B 1*	*C*	*C 1*	*D*	*D 1*
1941	7·4	6·6	22·9	7·9	26	44
1942	6·0	4·6	23·52	16·62	40·10	46·15
1943	6·6	4·8	21·7	16·9	38·8	45·3
1946	6·6	5·3	22·8	15·7	37·3	41·3

The small inconsistencies in counts of deaths are due to (1) scoring by different observers in successive years, (2) moribund plants reckoned as dead or not yet dead on different occasions, (3) dead plants disappearing or overlooked or overgrown by heather in later years.

It has been noted already that mortality in the D series is enormously higher than in the B series, while the C series occupies an intermediate position. The only additional fact of interest shown by the graphs is that in C 1 and D plants a large increase in the number of deaths occurred in the second year after planting, whereas in all other treatments any plants that succumbed did so in the first year. This curious behaviour is recorded although no explanation can be offered and it may be of little significance.

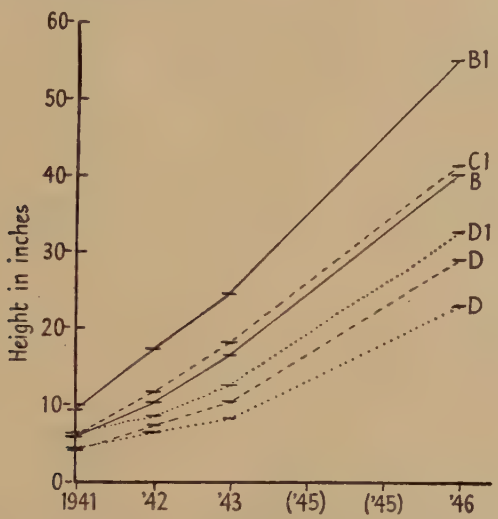


FIG. 3. Mean heights of trees under each treatment, B, C, D, in successive years (see Table III). B 1, C 1, D 1 received phosphate at planting.

Assessments for mean height in successive years are given in Table III and recorded graphically in Fig. 3. The chief interest of these records is persistence of the differential rate of growth in the three treatments. Six years after planting the B series remain well ahead of the D series, with C in an intermediate position.

TABLE III. *Mean heights of plants in successive years after planting*

	B	*B 1*	*C*	*C 1*	*D*	*D 1*
1941	5·9	9·3	4·2	6·0	4·4	6·5
1942	10·36	17·34	7·23	11·90	6·50	8·62
1943	16·7	24·7	10·5	18·1	8·4	12·7
1946	40·3	55·4	29·1	41·7	23·09	32·8

Assessments for mean length of current year's shoot are given in Table IV and recorded graphically in Fig. 4. A point of interest here is the increased stimulus to shoot elongation in 1942, 2 years from the application of phosphate, suggesting that the maximum effect is not produced until 2 years after application and that by the third year the stimulus to growth has largely disappeared.

TABLE IV. *Mean lengths of current year's shoot in successive years after planting*

	B	*B 1*	*C*	*C 1*	*D*	*D 1*
1941	2·2	4·9	1·4	2·7	1·4	2·8
1942	4·05	7·84	2·62	5·86	1·81	3·18
1943	6·2	8·3	3·7	6·6	2·5	4·5
1946	10·3	11·8	6·6	9·4	6·7	8·9

In the B and C series there is to be noted a marked but transient stimulus to shoot elongation in 1942, following application of phosphate at planting in 1940. This stimulus is not shown by the D series.

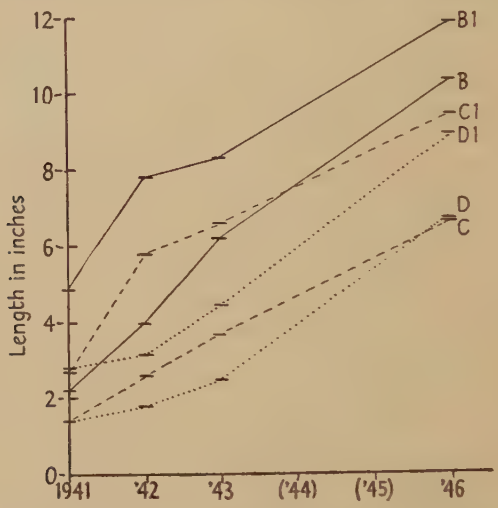


FIG. 4. Mean lengths of shoots of current year's growth under each treatment, B, C, D, in successive years (see Table IV). B 1, C 1, D 1 received phosphate at planting.

It may be emphasized that the site of this experiment is particularly bleak and exposed, and the soil is of very poor type. On a better site the differences might have been less striking.

DISCUSSION.

The plants which grew best and among which losses were below 10 per cent. in this experiment were raised and grown on Wareham Forest soil, with addition of compost at the rate of 20 tons per acre, applied to seed-beds and to transplant ground. The cost of such treatment in nurseries is not unduly high. At the time of the experiment it was calculated at £25 per acre, of which £15 per acre represented the cost of the hop-waste, at that time. Assuming that the effect of the dressing lasts for 3 years, the cost per annum is only £8, which does not add substantially to the cost of the plants—about 1½*d.* for seedlings and 8*d.* for transplants, per thousand. Doubling these figures for increased costs still involves no excessive rise in cost of plants. The reduction of losses in the field from, say,

30 per cent. to 7 per cent. would far outweigh the increase in the cost of production, due to compost treatment in the nursery. As compared with those in B plots, the D plants suffered far higher losses—up to 45 per cent.—and are much inferior in growth when removed to relatively severe and unfavourable permanent quarters in the forest. The assumption that all or part of the more vigorous growth of the B plants, that followed planting and still continues, was due to addition of compost further reduces the calculated cost of the nursery treatment. Later it has been learned that composts other than the hop-waste product used, e.g. those made from equal parts of hop-waste and bracken, or from bracken alone with a small addition of phosphate, produce equally good if not better effects on growth, in this soil. It has also been learned that the effect of a first application of compost at 20 tons per acre, or 10 lb. per square yard, with very heavy stocking of the seed beds, lasts for 2 years without sensible diminution.

The effects produced by transplanting Wareham-raised plants for 1 year to standard nursery conditions is interesting. The values for losses and mean rates of growth are in every case intermediate between those observed in the other two series, although few of the individual differences are statistically significant, those of the percentage mortality values approaching significance most nearly.

From a botanical standpoint and in respect of its practical application, the conclusion that emerges most clearly from the observations now recorded is believed to be one directly related to the condition of the roots of the experimental plants at planting and during subsequent growth. The root systems of the B plants raised in a natural soil of extremely poor quality, with addition of compost, were well furnished with clusters of short roots. All of these roots were forked mycorrhizas of the normal ectotrophic type formed by association with the fungus *Boletus bovinus*, mycelium of which is widely distributed throughout the soil of Wareham Forest. Before the advent of actively growing trees on the area and the ensuing soil changes, mycelium of this Hymenomycete was known to form mycorrhizas, sluggishly and with apparent difficulty, with both Scots pine (*Pinus sylvestris* L.) and Corsican pine in untreated soil. Addition of compost rapidly activates mycorrhizal activity, so producing root systems of normal type, with abundant mycorrhizas. The root systems of the B plants raised in a natural soil with addition of compost are those normal for seedlings of the latter species of pine. If comparison had been possible at the time, they would have been found to resemble closely those of naturally regenerating seedlings in a Corsican forest. This type of root system was present in the field transplants 2 years from planting and persists in root samples examined in 1947, the seventh year from planting. It is believed to play a decisive role in their observed growth reactions. In contrast, roots of the D plants were non-mycorrhizal, a condition constantly recorded for this and other species of pine and spruce raised in the nursery in question. The non-mycorrhizal type of root system was feebly activated by phosphate treatment but persisted in the D plants 2 years from planting. Comparative poverty in mycorrhizal equipment is still a feature of the root system of the D series of plants. It is believed that this difference in

mycorrhizal behaviour is the most significant factor underlying the behaviour of the two sets of plants.

The condition of the roots of the C plants was intermediate in respect to mycorrhizal activity, as in other features. It is noticeable, however, that the capacity for response to phosphate treatment at planting was markedly greater than in the D series, as expressed in improved shoot growth and mycorrhizal equipment. It is tempting to conclude that greater constitutional vigour, persisting from the earlier nursery period, is related directly to this feature of the C as compared with the D series, and also to the reduced mortality and more vigorous growth.

If the observations now recorded carry a lesson for practical foresters, it may be summarized in general terms as follows:

Certain coniferous genera, in common with other groups of trees, form mycorrhizal association with soil fungi belonging to the Higher Basidiomycetes, many species of which have a very wide geographical distribution and are among the commonest soil fungi of woodland soils in many parts of the world. A number of the species concerned have been isolated and grown as pure cultures on synthetic media. Using certain precautions in respect to sterilization, some of them can also be grown in soil in laboratory culture. They show peculiarities in respect to nutrition and are often difficult to maintain in culture. Little is known about their ecology in nature, but it may be inferred that their distribution in natural soils and the physiological state of their mycelia in respect to mycorrhizal activity is conditioned by factors such as the soil reaction and the character of the humus constituents.

To ensure the raising of nursery stock with root systems normal for the species in respect to mycorrhizal equipment, attention should be directed to providing and fostering mycorrhizal activity in nursery soils, not only by securing the presence of appropriate fungi but by maintaining soil conditions that favour their activity and proper functioning. More especially is this true for transplants destined for planting in soils of non-forest type, from some of which suitable fungi may be absent. If the view is correct—and it will be found difficult to disprove—that mycorrhizal activity is a formal condition for healthy growth in pine and spruce, as in other genera of mycorrhiza-forming trees, the root structure of nursery seedlings of these trees in respect to this activity affords valuable criteria of the suitability or otherwise of existing soil conditions in the nursery.

Transplants sent out from the nursery without full mycorrhizal equipment suffer heavy mortality if planted in unfavourable soil conditions, apart from the delayed growth shown by the survivors until they have developed a normal root system.

In the present instance, it is the comparative mortality figures that are of outstanding economic importance.

SUMMARY.

1. The object of the experiment described was to compare survival and growth of two-year old Corsican pine transplants of different nursery origins on extremely poor heath land in an exposed situation.

2. Plants of three different origins were used:

(1) Raised in the same poor heath soil with addition of compost; lined-out for one year in similar soil with addition of compost.

(2) Raised by 'standard nursery methods'; lined-out for one year in the same nursery.

(3) Raised as in (1); lined-out for one year as in (2).

The plantings were duplicated in each group, one series being supplied with phosphates in the form of basic slag at planting. All treatments were quadruplicated in randomized plots.

3. In survival, and in shoot growth and general health and vigour, the plants raised on poor heath soil with compost and lined-out in the same soil with compost were greatly superior to the corresponding plants, raised and lined-out in a 'standard nursery'. In particular, the death-rate of the latter was very heavy and was increased by supplying phosphate at planting. Those raised in heath soil with compost and lined-out in the 'standard nursery' occupy a median position.

4. A supply of phosphate at planting benefited growth in all series, but plants in the untreated series of those raised in heath soil with compost were as good or better than those receiving compost in the other series.

5. The root systems of plants raised in heath soil with compost were well supplied with short roots and mycorrhizas at planting and throughout growth. Those of the nursery transplants were very deficient in short roots and were without mycorrhizas.

6. The experiment illustrates the fact that the constitutional vigour of seedlings of Corsican pine raised in soil conditions that ensure possession of a normal root system with adequate mycorrhizal equipment is carried into the forest, even when plantings are made in extremely poor soils of non-forest type. It follows that for this species, as doubtless for others, the use of soil treatments to ensure the production of seedlings that satisfy these requirements may be restricted to the nursery.

7. The application of this conclusion to tree nurseries in general is discussed.

LITERATURE REFERENCES.

(1) Mitchell, H. L.: *The Growth and Nutrition of White Pine* (*Pinus strobus* L.) *Seedlings in Cultures with varying Nitrogen, Phosphorus, Potassium, and Calcium.* Black Rock Forest, Bull. No. 9, 1939.

(2) Olsen, R. V.: 'The Use of Hydroponics in the Practice of Forestry'. *Journal of Forestry*, xlii. 264–8, 1944. (See also *Forestry Abstracts*, vi, No. 2, p. 90.)

(3) Rayner, M. C.: 'Mycorrhiza in Relation to Forestry. I. Researches on the genus *Pinus*, with an account of experimental work in a selected area'. *Forestry*, viii. 96–125, 1934.
(4) —— 'Mycorrhizal Association in Scots Pine'. Ibid. ix. 154–5, 1935.
(5) —— 'The Mycorrhizal Habit in Relation to Forestry. II. Organic Composts and the Growth of Young Trees'. Ibid. x. 1–22, 1936.
(6) —— 'The Mycorrhizal Habit in Relation to Forestry. III. Organic Composts and the Growth of Young Trees'. Ibid. xiii. 19–35, 1939.
(7) —— and Levisohn, I. 'The Mycorrhizal Habit in Relation to Forestry. IV. Studies in Mycorrhizal Response in *Pinus* and other Conifers'. Ibid. xv. 1–36, 1941.

Representative plants, three years from sowing, from planting of Corsican pine (*Pinus nigra* var. *calabrica* Schneid.). For condition of roots see p. 208.

B, B 1: raised and lined-out in heath soil with compost
C, C 1: raised in heath soil with compost; lined-out in 'standard' nursery
D, D 1: raised and lined-out in 'standard' nursery

B 1, C 1, D 1 received phosphate at planting

PLATE X

PRELIMINARY NOTE ON A DISEASE OF SITKA SPRUCE IN CAIRNHILL PLANTATION, DURRIS, KINCARDINESHIRE (*Picea sitchensis* Carr.)

By E. V. LAING

(*Forestry Department, University of Aberdeen*)

INTRODUCTION.

A LARGE number of trees in Cairnhill Plantation, Durris, Kincardineshire, have been for some years in a diseased condition. A few have died, some more may die, some are badly shaped, and the majority show a considerable exudation of resin from the bark.

The trouble was first noted subsequent to brashing and pruning. Three years ago *Nectria curcurbitula* Ft. fructifications were found plentifully on the bark.

HISTORY OF PLANTATION.

The history and description of the plantation up to the year 1936 has been given fully by Dr. G. K. Fraser (3). Briefly stated, the plantation was formed in 1909–10. Sitka spruce were used at 6-foot spacing, interspersed with Norway spruce (*Picea abies* Karst.), so that the actual spacing was 3 feet.

The soil is variable, four types being distinguished. The growth of the trees was irregular, the variations being correlated with the soil and vegetation types.

The plantation was left untreated until 1934, when it was brashed and pruned. Pruning was done up to 15 feet, and is understood to have been done carefully.

EXAMINATION OF TREES.

The following counts have been made in the plantation:

Pruned trees

Healthy	150
Slight attack, now healed	9
1st stage of disease	194
2nd stage ,,	30
3rd stage ,,	9
Indefinite	6

Brashed trees

Healthy	364
Slight attack, now healed	11
1st stage of disease	317
2nd stage ,,	37
3rd stage ,,	5
Indefinite	13

Untouched trees, i.e. neither pruned nor brashed

Healthy	47
1st stage of disease	10
2nd stage „	1

The data show that many trees remained healthy after pruning or brashing. It is interesting that some trees which were neither pruned nor brashed became diseased.

In the above classification trees in the third stage, i.e. heavily attacked trees, have fluted stems. Cross-sections of such stems are revealing. It is evident that parts of the cambium were killed after brashing or pruning. Growth continued in the areas between the branches so that now the stems show pronounced ridges.

The difference in the ring counts opposite the branches and between the branches is 9 to 11 rings, i.e. death of the cambium occurred from 1935 to 1937, just subsequent to the pruning or brashing. The lesions are narrow, running up and down the stems. In some cases there are cracks which are attributed to the unequal growth of the stems.

An examination of the dead bark shows abundant mycelium, and in the fissures there are abundant spores which correspond to the unicellular oval conidia of *Nectria cucurbitula*. As already noted three years ago, the dark red stomata of the ascus stage of *Nectria cucurbitula* were found round the lesions.

A feature of the bark of the trees is the abnormal lenticel development. At one stage in the growth of the tree there must have been extremely well-developed aerenchyma, which indicates excessively moist conditions of the soil or atmosphere, or both, of the plantation.

An attempt has been made to correlate the incidence of the disease with soil type and vegetation and the growth of the trees. In Meadow Flush there are 92 trees attacked, including 7 of probably the first-diseased trees: in wet *Calluna* heath there are 275 infected trees, with 4 of the originally attacked trees: in peaty heath ground there are 61 diseased trees: on wetter *Calluna* heath there are 73, with 2 originally attacked trees. It seems that there is no correlation between infestation and vigour of trees and soil and vegetation type. Trees have been attacked on all sites.

PATHOGENICITY OF *NECTRIA CUCURBITULA*.

This fungus was extremely well known on the continent of Europe last century. It was recorded by De Bary (2), Hartig and Von Tubeuf (8), who described it as a serious pest of spruce trees. Massie (4) describes it from European experience. Massie says it had been shown by Hartig to be a destructive wound parasite on spruce especially, although it is also recorded as attacking silver fir (*Abies alba* Mill.) and Scots pine (*Pinus sylvestris* L.). The bark is attacked, an entrance being effected through wounds made by the larvae of the moth *Grapholitha pactolana* Zell., and also through bruises caused by hailstones or broken branches. The spores, both conidia and ascospores, germinate on the resin surrounding a wound, and the mycelium penetrates the cambial zone. It spreads to the bast, growing most actively during the winter months when the growth of the tree

is at a standstill. Some time after infection the bark is killed and dries up during the summer, while the branch dies beyond the point of infection. De Bary (2) records that the fungus spreads rapidly, covering a distance of 10 cm., in a longitudinal direction in one season. Lateral spread is small.

The writer found this fungus in 1928 as a secondary cause of deaths in a section of transplants of European larch in a nursery. It followed wounding of the trees at the collar with the spade in lining-out. This observation was not published.

In the Forestry Museum of Aberdeen University there is a preparation by the late Professor A. W. Borthwick showing Norway spruce bark killed by *Nectria cucurbitula*. The fructifications are developed in great abundance on the portions of the bark in the neighbourhood of the branches and also along the bark, up and down from the scars. There is unfortunately no information as to where or when the specimens were collected.

Gilbert Brown (1) describes *Nectria cucurbitula* as often attacking spruces and to a less extent silver fir and pines. Stevenson's *Mycologia Scotica* (7) gives *Nectria cucurbitula* as found in areas Tay and Moray.

THE MOTH *GRAPHOLITHA PACTOLANA* ZELL.

This moth, which is mentioned in the continental literature as a likely agent in forming the wounds through which the spores of *Nectria cucurbitula* gain entrance, is now known as *Laspeyresia pactolana* Zell. In the *Ento. Mon. Mag.*, vol. x, p. 224, 1874, Morayshire and Braemar are mentioned as localities in which it is found. Meyrick's *Handbook of the British Lepidoptera*, 1895 (5), gives it as found in Aberdeen, Moray (local), and not recorded elsewhere. Meyrick's new edition (6) gives it as from Perth to Sutherland, local, but is not specific as to the tree on which it occurs.

So far no trace of this moth has been found on diseased trees in the Cairnhill plantation.

DISCUSSION.

The literature shows that *Nectria cucurbitula* is a wound parasite. It also lives saprophytically on branches and logs. The condition of the Cairnhill plantation at and previous to the pruning and brashing would have provided in all probability suitable conditions for its development as a saprophyte. The trees were closely grown, the atmosphere as indicated by the abundant aerenchyma on the stems must have been humid in the extreme, and it is very probable that the fungus may have been present as a saprophyte. The wound provided a very suitable medium for the germination of the spores.

The possibility of the moth *Laspeyresia pactolana* playing a part must not be ruled out. Further investigation is necessary, however.

ACKNOWLEDGEMENTS.

The writer of the note is indebted to the Forestry Commission for permission to examine the plantation, and particularly to Mr. T. H. Woolridge for his co-operation and help in every way.

SUMMARY.

A disease of Sitka spruce at Cairnhill, Durris, is attributed to the fungus *Nectria cucurbitula* E. The fungus followed pruning and brashing of the trees. Some untouched trees, however, have also been attacked. The fungus in Europe is a well-known wound parasite and is associated there with the moth *Laspeyresia* (*Grapholitha*) *pactolana* Zell.

LITERATURE REFERENCES.

(1) Brown, G.: 'Nectria on Larch'. *Trans. Royal Scot. Arb. Soc.*, vol. xvii, pt. 2, p. 344. 1904.
(2) De Bary: *Comparative Morphology and Biology of the Fungi*, p. 383, 1887.
(3) Fraser, G. K.: *Forestry*, vol. x, No. 2, pp. 110–23.
(4) Massie, G.: *Diseases of Cultivated Plants and Trees*, p. 185, 1910.
(5) Meyrick, E.: *Handbook of the British Lepidoptera*, 1895.
(6) —— *Revised Handbook of the British Lepidoptera*, 1927.
(7) Stevenson, J.: *Mycologia Scotica*, p. 360, 1879.
(8) Tubeuf and Smith: *Diseases of Plants*, p. 188, 1897.

PISSODES VALIDIROSTRIS GYLL., IN SHOOTS OF *PINUS SYLVESTRIS* L.

By MYLES CROOKE

(*Forestry Department, University of Aberdeen*)

INTRODUCTORY.

ON 7th May 1947, at the invitation of Mr. T. H. Woolridge, District Officer, Forestry Commission, the writer examined a young Scots pine (*Pinus sylvestris* L.) plantation which was showing indications of damage by some insect pest. It formed part of the Inglismaldie Forest, situated on a flat area 100 feet above sea-level, immediately to the north of the river Esk, about 5 miles north-east of Brechin, in the county of Angus. The soil is a sand over gravel and is thus well suited to pine. The trees are growing vigorously and at 8 years of age have attained an average height of some 12 feet; in particular, the leading shoots are exceptionally large and strong.

The damage to the infested trees was very obvious, because in nearly all cases the leading shoots had been attacked, and these had lost a large proportion of their needles and had turned brown. On dissection, typical weevil larvae were found boring up the shoots. They were light lemon in colour, measuring 6–7 mm. in length. Identification at this stage was impossible and the shoots were therefore placed in breeding-cages to allow of the completion of the life-cycle to the adult stage. On emergence, the beetles were identified as *Pissodes validirostris* Gyll., a species which has been recorded in Great Britain on only one previous occasion.

HISTORICAL SUMMARY AND GENERAL ACCOUNT OF THE GENUS.

The genus *Pissodes* Gm. contains, in Great Britain, the three species *P. pini* L., *P. notatus* F., and *P. validirostris* Gyll. *P. piniphilus* Hbst. is not accepted as a British species by either Hudson-Beare (4) or by Kloet and Hincks (5), although it has been found occasionally and is recorded by MacDougall (9) on imported timber is Sunderland. There is no proof, however, that it has become established as a breeding-species. *P. pini* and *P. notatus* are both well-known pests of coniferous trees, the former usually attacking older, and the latter younger, trees. *P. pini* is injurious in the larval stage to Scots pine and spruce of over 15 years of age, and causes damage by boring in the cambial layer in all parts of the tree from crown to roots. The larvae of *P. notatus* usually feed on the lower part of the stem of pines of 10 years of age or less. *P. validirostris*, first recorded in this country by Laidlaw in 1930 (6), when he bred a single specimen from material from Morayshire, is known on the Continent as the cone-breeding species of the genus, and has not previously been recorded as occurring in shoots.

MacDougall in 1898 (9), after breeding *P. notatus* in Scots pine cones,

contended that *P. validirostris* and *P. notatus* were identical, but Torka in 1905 (11) successfully differentiated the two species, and since that date all subsequent writers have accepted the validity of the species *P. validirostris*. Laidlaw (6, 7), in two papers in which he records the first occurrence of *P. validirostris* in Great Britain, gives an excellent comparative account of the genus and utilizes information contained in Escherich's *Die Forstinsekten Mitteleuropas* (3), including details of the life-cycle and a key for the distinction of the seven European species of the genus.

Escherich states that the larvae of *P. validirostris* occur in the cones of Scots (*Pinus sylvestris* L.) and Austrian (*Pinus nigra* var. *austriaca* Asch. and Graebn.) pines, and that as many as three larvae may be found in one cone. The infested cone turns yellow-green in colour and is usually distorted, the scales being less prominent, due to the defective development of the seed. The generation is a yearly one, and it appears that oviposition takes place in the second summer of the cone's life when it has reached full size but is still in a succulent state.

The present record of *P. validirostris* in shoots appears to be unique. It is interesting to note that this habitat is closely analogous to, if not identical with, that adopted by some species of *Pissodes* found in North America. Doane, Van Dyke, Chamberlin, and Burke (2) describe the damage caused by *Pissodes* in that area and mention, amongst others, *P. strobi* and *P. terminalis* as being most destructive species. *P. strobi* is most common in north-eastern America and causes great damage in nursery stock and young plantations by boring, in the larval stage, in both terminal and side shoots of white pine (*Pinus strobus* L.) and spruce. *P. terminalis*, which occurs on the Pacific coast, is confined to lodgepole pine (*Pinus contorta* Engelm.) and, in the larval stage, attacks them, as the name suggests, by boring up the leading shoots. The systematic position of the American species is described by Blatchley and Leng (1).

DESCRIPTION OF BEETLE (see Plate I).

The following description of the adult beetle was prepared after examination of the characters of the thirteen specimens bred out from the Inglismaldie material.

The beetle measures 7–8 mm. in length, including the rostrum. The elytra carry two transverse bands of light-coloured pubescence; the anterior band not continuous across the suture, and thus reduced to two spots, which are orange-red in colour; the posterior band continuous across the whole width of the elytra, broader on the outside and narrowing towards the middle, usually orange-red on the outside and white on the inside, but sometimes uniformly orange-red throughout. In addition to these two main areas of pubescence, scattered whitish scales occur along the line of the suture and towards the posterior end of the elytra. The rows of punctures on the elytra are very variable: on some specimens the punctures are large and rectangular, on others small and rounded. The thorax is uniformly pitted except for a central longitudinal line free from punctures; pubescence varying from white through yellow to orange and aggregated in four distinct spots in a transverse line across the middle of the thorax, with

some scattered scales along the margins; the hind angles right-angled, not protruding.

It is worthy of note that a very wide range of coloration and of form in the elytral punctures was found, and that this variation led to difficulty in the identification of the beetle. It was eventually decided, however, that the beetle conformed most closely to the published descriptions of *P. validirostris*.

The above description differs from that given by Escherich in three main points. That author states: first, that the average length is from 5 to 6 mm. (with or without rostrum, however, unstated); secondly, that the pubescence on the elytra is yellow; and thirdly, that the punctures on the elytra are constant in form, being non-rectangular and non-pitted. This last character he considers to be sound enough for use in his key for the determination of the species.

Laidlaw also disagrees with Escherich's description of the elytral coloration, stating that in the specimen he bred out the bands were terracotta-coloured. He figures the adult as being 8 mm. in length, but makes no reference to the punctuation.

DAMAGE CAUSED (see Plate II).

The material from which the following observations were made consisted of the original shoots collected on the 7th May and of a much larger consignment of shoots received on the 4th June, after the decision had been taken to remove all infested shoots from the plantation. In all, 99 shoots were collected, 95 of which were leading shoots and 4 were side shoots. The majority of the leading shoots were exceptionally large, averaging 2 feet in length with a basal diameter of just over 1 inch.

Each shoot was found to contain from 1 to 7 larvae, the average number being 3 or 4. The larvae occurred boring up the interior of the shoot and were usually restricted to the basal 6 inches, although in some cases they had penetrated throughout the entire length of the shoot. The tunnels formed by the larvae were very obvious and were filled with a light brown, finely divided, compacted frass. The remainder of the interior of the shoot was usually of a very dark brown colour, the structure being almost completely destroyed, whilst the bark was dead, brown and brittle, and the needles dead and fallen. In some cases, however, and especially in those shoots which contained only one or two larvae, the length above the region of larval activity was undamaged, the bark being fresh and green and the majority of the needles still alive. It is extremely unlikely, however, that even in this latter condition the leading shoot would have been able to recover from the attack. It must therefore be assumed that in a very high percentage of the infested shoots death of the shoot must be the normal result of attack.

OBSERVATIONS ON LIFE-CYCLE.

Shoots were examined at frequent intervals throughout the summer months, and the following details of the development of the insect were obtained.

The larval stage lasted until approximately 9th June, and the majority of the

imagos were completely formed by the 8th July but did not commence to emerge from the shoots until much later. The writer has recorded emergences from the 20th July until the 9th August; these emergences took place through a circular bore hole of 3 mm. in diameter in the side of the shoot. A total of thirteen adults emerged, showing that there was a very high rate of mortality amongst the larvae and pupae: the reasons for this will be discussed below.

The writer also originally intended to carry out a series of breeding experiments to determine whether or not the beetle could be made to attack both shoots and cones, but this was found to be impossible because of the insufficient numbers of the beetle available after the necessary specimens had been prepared for identification.

PARASITES.

The material collected on the 7th May yielded 6 Ichneumon parasites, 3 males and 3 females, which were identified as *Ephialtes sagax* var. *laticeps* Ratz. These parasites emerged between the 12th and the 22nd May, as follows: 2 ♂♂ on the 12th; 1 ♂ and 1 ♀ on the 13th; 1 ♀ on the 21st; and 1 ♀ on the 22nd. It will be noted that these emergences took place before the larger consignment of material was obtained; and therefore if, as seems probable, this latter material was also parasitized by *E. sagax* var. *laticeps*, no record of it could have been obtained. On the assumption that the rate of parasitism was more or less uniform in all the infested shoots, it seems probable that *E. sagax* var. *laticeps* plays a fairly large part in the suppression of any infestation by *P. validirostris*, since 6 parasites were obtained from an estimated 24 larvae in the 7 shoots, representing a parasitism of 25 per cent. In this connexion it is interesting to note that Dr. W. B. R. Laidlaw has informed the writer that in the present year he has reared some specimens of *E. sagax* var. *laticeps* from *Pinus contorta* cones collected in the Roseisle (Morayshire) district, which were believed to have been infested by *P. validirostris*. No conclusive proof of the presence of *P. validirostris* was obtained, however, although a single elytron, closely resembling that of the specimen of *P. validirostris* in the collection of Dr. Laidlaw, was removed from one of the cones. The difference between *E. sagax* and *E. sagax* var. *laticeps* is small, the variety being said to have the temples behind the eyes slightly wider than those of *E. sagax*. *E. sagax* is recorded as a parasite of *Evetria buoliana* Schiff. In *Ephialtes*, as with most Ichneumons, the habitat is of more importance than the host, a fact of some importance in this case, where the damage caused by *P. validirostris* is of the same general type as that caused by *Evetria buoliana*. The variety is said to have been bred originally from fir cones together with *P. notata*. (Information from J. F. Perkins, in correspondence.)

The only other parasite recorded by the writer is the Braconid, *Calyptus mucronatus* Thunb., a single female of which emerged on the 12th June. This species has been recorded by Laidlaw (8) as a parasite of *P. validirostris*, and the present record is of interest in view of his suggestion that *C. mucronatus* may be a specific parasite of *P. validirostris*. No information is available as to whether or not *C. mucronatus* has been recorded from any other host.

The assumed uniformly high rate of parasitism accounts, in part, for the very high rate of mortality in the immature stages of the beetle, referred to above. This view is strengthened by the discovery during the periodical examinations of the material of dead and apparently parasitized larvae of *P. validirostris*, and of cocoons similar to that of *Ephialtes sagax* var. *laticeps* obtained from the original material. It cannot be claimed, however, that this is the sole reason for the death of so many of the immature *P. validirostris*, and it is thought that the physical conditions, particularly that of humidity, in the breeding-cages may have been adverse to the development of the beetle.

PRELIMINARY NOTES ON FOREST STATUS.

The reasons for the present small and isolated attack by *P. validirostris* in its new habitat are obscure, particularly in view of the fact that a sufficiency of the normal material utilized for breeding purposes was present both in the plantation in question and in woods closely adjacent to it. A large number of cones from the area was examined, but in none were any traces of the workings of *P. validirostris* found. However, this cannot be taken as conclusive proof that no beetles were present in the cones, since it was quite impossible to make an intensive examination of the very large number of cones present. There can be little doubt that if the beetle were to increase its numbers and distribution and retain its habitat in shoots, it would be a pest of some note in areas of young Scots pine. At present, however, it is not of sufficient importance to warrant its being classed as a serious forest pest, even although it appears to have the faculty of attacking healthy and vigorous trees. The attacked plantation at Inglismaldie is being kept under observation. At the date of writing, indications of the recurrence of the attack have been noted, although the infestation appears to be on a much smaller scale than that of the previous attack. It is too early, however, to assess the intensity of the attack with any accuracy, because the infested shoots have not yet lost their needles and turned brown to such an extent as will occur later in the season. It is hoped that foresters will be on the look-out for any indication of a similar attack, about which the writer would be pleased to receive information.

The only control measure which can be advocated is the cutting out and destruction of the infested shoots, but it would seem to be advisable to delay this operation until the middle of June, a date by which the natural enemies of the beetle will have emerged, prior to the emergence of the beetles themselves.

SUMMARY.

The discovery of an attack by *P. validirostris* Gyll. on a plantation of young Scots pine is described, attention being drawn to the fact that *P. validirostris* was found occurring in shoots and not in cones as is usually the case. This is followed by an account of the genus *Pissodes* in Great Britain and of the literature in question. The beetle and the damage caused by the larvae are described, and a section is devoted to their parasites, of which two, *Ephialtes sagax* var. *laticeps*

Ratz. and *Calyptus mucronatus* Thunb., were reared. The paper is concluded by a short note on the forest status of the beetle.

ACKNOWLEDGEMENTS.

The writer wishes to express his indebtedness to Dr. W. B. R. Laidlaw for advice and information on his original record of *P. validirostris* and on the parasites bred in 1947, and for the provision of the figures of *E. sagax* var. *laticeps*; to Mr. T. H. Woolridge for assistance in the field examinations; to the members of the staff of the Department of Entomology of the British Museum for the necessary identifications carried out by them; to Mr. A. Hill of the North East of Scotland College of Agriculture for photographing the larval damage; and to Professor H. M. Steven and Dr. E. V. Laing for their advice during the preparation of this paper.

LITERATURE REFERENCES.

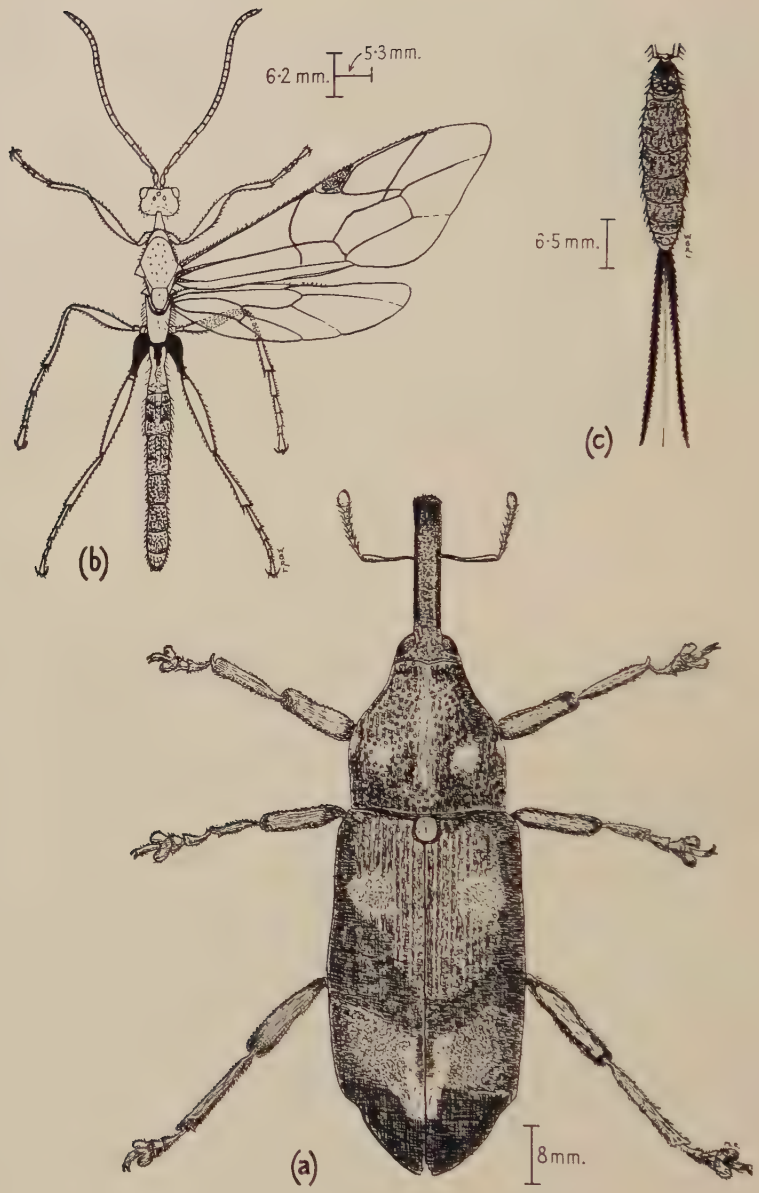
(1) Blatchley, W. S., and Leng, C. W.: *Rhynchophora or Weevils of North-eastern America.* Nature Publishing Co., Indianapolis, Ind., 1916.
(2) Doane, A. W., Van Dyke, E. C., Chamberlin, W. S., and Burke, H. E.: *Forest Insects.* McGraw Hill Book Co. Inc., New York and London, 1936.
(3) Escherich: *Die Forstinsekten Mitteleuropas*, 1923.
(4) Hudson-Beare: *Cat. Coleop. Brit. Isles.* Jonson & Sons, London, 1930.
(5) Kloet and Hincks: *Check List of British Insects*, 1945.
(6) Laidlaw, W. B. R.: '*Pissodes validirostris* Gyll., with Braconid Parasite from Morayshire'. *Scot. For. Journ.* xliv, Pt. 2, pp. 90–1, 1930.
(7) —— 'The Pine Cone Weevil (*Pissodes validirostris*) in Britain: With a Brief Comparative Account of the Genus'. *Scot. Nat.*, 1931.
(8) —— 'Two British Parasites of *Pissodes*'. *Scots. For. Journ.* xlvii, Pt. 1, pp. 24–31.
(9) MacDougall: *Proc. Royal Phys. Soc. Edinburgh*, xiv. 64, 1898.
(10) —— Ibid. xxiii. 346, 1899–1900.
(11) Torka: *Zeitschr. d. nat. Abt. d. Deutsch. Ges. f. Kunst. u. Wissenschaft in Possen*, xi (1904), p. 6, and xii (1905), p. 8.

PLATE XI

(*a*) Leading whorl of Scots pine with leading shoot attacked by larvae of *P. validirostris* Gyll., showing discoloration and loss of needles. Length of leading shoot, 28 inches

(*b*) Section of leading shoot figured in (*a*) showing four larvae *in situ* and the damage caused by them. Length of section, 7 inches, beginning 3 inches from base of shoot

Photograph October 1947



(*a*) *Pissodes validirostris* Gyll.
(*b*) *Ephialtes sagax* var. *laticeps* Ratz., male
(*c*) *Ephialtes sagax* var. *laticeps* Ratz., female abdomen

PLATE XII

SOCIETY'S AND OTHER NEWS

NEW CONSTITUTION AND RULES

The new Constitution and Rules, based on the recommendations of the Special Committee appointed at the 19th Annual General Meeting in 1946 and adjusted and passed at the 20th Annual General Meeting in 1947, were confirmed at an Extraordinary General Meeting of the Society in London on 17th December 1947 and became operative as from that date.

The main change has been the introduction of more exacting qualifications for Fellowship. All those who were Fellows immediately before the new Constitution and Rules became operative will be continued as Fellows but will be liable for the new rate of subscription (one and a half guineas) which can be redeemed for life by paying the appropriate lump sum. Others who wish to become Fellows will first have to be Professional Associates for five years and thereafter have the following technical qualifications: hold a degree or diploma, have had five years of experience, and had a thesis approved or an article published. Fuller details of these requirements will be found in Article V (*a*) of the Constitution.

A new Class known as Professional Associates has been created and the qualifications here are similar to those for Fellowship under the old constitution, i.e. either hold a degree or diploma, or have made important contributions to forestry, or hold a post normally held by a degree man. Fuller details will be found in Article V (*b*) of the Constitution. The annual subscription is one guinea. Associates under the old constitution have the option until 17th March 1948 of becoming Professional Associates.

Another new Class is that of Professional Member, which corresponds to the former Order of Associates and has the same annual subscription rate of half a guinea. This will be the usual class for foresters in either State or private service. For details see Article V (*c*).

Ordinary Membership, under Article V (*d*), is the same as under the old constitution, with the same annual subscription of one guinea. This class is for those who are not professional foresters.

The management of the Society will be mainly in the hands of the Fellows and Professional Associates, but the Professional Members will be able in alternate years to elect one of their own class as a member of Council.

EXCURSION AND ANNUAL GENERAL MEETING, 1948

At the 20th Annual General Meeting held at Lossiemouth on 24th September 1947 it was tentatively decided to hold the next excursion and annual general meeting in the Dukeries district in September 1948, if suitable arrangements could be made. The Meetings Committee has the matter in hand.

BACK NUMBERS OF *FORESTRY*

The Council would like to provide a complete set of *Forestry* for the library at each of the Forester Training Schools in Britain, but is short of copies of Vol. I, No. 1 (1927) and Vol. II, No. 1 (1928). If anyone has a spare copy of either and would care to send it to the Secretary at 8 Rutland Square, Edinburgh, 1, the Council would be very grateful.

ANNUAL EXCURSION OF SEPTEMBER 1947

Based on Lossiemouth, Morayshire

The second post-war excursion was held at Lossiemouth on 24th to 26th September 1947 and was attended by about thirty members, in spite of the rather long and expensive journey. There was strong representation from the Forestry Commission, one of the university schools, and private forestry. The discussions in the field and in the evenings were keen and to the point. The Society is greatly indebted to the Forestry Commission and to the Earl of Moray for the facilities and guidance provided. Messrs. F. Oliver, J. A. M. Kennedy, W. G. Milne, J. A. Lamb, D. M. Watt, J. A. B. Macdonald, J. Farquhar, and J. G. Reid demonstrated in the State forests and nurseries, and the Earl of Moray and Mr. Matthew Feaks in the private woodlands. Space permits only very brief references to some of the most interesting things seen.

Culbin Sands

On the bare sand-dunes which require fixation the need for planting parallel with the southern coast of the Moray Firth, from west to east, with the prevailing wind and sand movement was brought out. The pre-war cost was about £20 per acre; the current cost is about £30. Thatching the moving sand with cut broom, birch, &c., succeeds better than planting the sand with marram grass (*Ammophila* (*Psamma*) *arenaria*). The trees planted are Corsican pine (*Pinus nigra* var. *calabrica*) on the sand-hills and Scots pine (*P. sylvestris*) and lodgepole pine (*P. contorta*) on the fixed heather. The production of the Scots pine is estimated at only about half that of the lodgepole per acre. Afforestation and drainage are drying the area. When first taken over by the Forestry Commission soon after 1914–18 many of the hollows were swampy and 'winter lakes' persisted until recent years. Surprising success has attended one small area of Douglas fir (*Pseudotsuga taxifolia*) mixed with Corsican pine, and even herbs such as *Goodyera repens* have appeared in the woods within 40-odd years of the afforestation of bare sand. The highest sand-hill is about 99 feet above sea-level. Recent measurements have shown that in places the sand has moved about 24 feet horizontally and piled up 7 feet vertically in 6 months.

Monaughty

Interesting problems in thinning, butt-rot of underplanted larch, &c., were demonstrated.

Darnaway

The Earl of Moray's very beautiful and productive woods were admired. The quality of Scots pine here and on the adjoining Altyre estates is among the best in Great Britain. The rotation is 80 years. The replanting target is 300 acres per annum. The woods have been under the skilled care of Mr. Feaks continuously since 1918, and from 1872 to 1917 were managed by his predecessor, Mr. Daniel Scott. So for some 75 years these two foresters have tended these woods, with gratifying results, in spite of the strain of two world wars. One experienced visitor thought the form of the Darnaway larch (*Larix decidua*) particularly good, and would have liked to see heavier thinnings of all the coniferous plantations, aiming at higher annual increment.

Teindland (*Findlay's Seat*)

On high ground 7 miles south-east of Elgin, at about 800 feet above sea-level, on typical thin peaty soil over a leached zone and a hard iron pan derived from Old Red Sandstone drift, the party saw a series of early experiments with ploughing, dressing with basic slag, &c., involving Scots pine and *Pinus contorta*, chiefly; also the nursing effect of *P. contorta* and *P. montana* on Norway and Sitka spruces. Very striking success was evident after two

growing seasons at about 650 feet in this area with transplanted 1-year seedlings of Sitka spruce (*Picea sitchensis*) from sterilized nursery plots. They compared very favourably with corresponding transplants from untreated nursery plots which had been 2 years in the seed-beds and 2 years lined out in the nursery before transplanting to the forest. If this success is confirmed in large-scale work, the potential saving on nurseries and costs of planting will be very substantial. It is possible that the technique is virtually one method of getting an uncontaminated soil in which the seedlings may make a good start.

FIFTH BRITISH EMPIRE FORESTRY CONFERENCE GREAT BRITAIN, 1947

The above Conference met in Great Britain from 16th June to 19th July 1947. The four previous meetings had been in Great Britain in 1920, Canada in 1923, Australia and New Zealand in 1928, and South Africa in 1935. The next meeting is planned for 1952, in Canada or India. Some 109 delegates attended; 43 from Great Britain and Northern Ireland, 9 from Canada, 12 from Australia, 2 from New Zealand, 4 from South Africa, 4 from Ireland—Eire, 10 from India, 4 from Burma, 1 from Newfoundland, 1 from Southern Rhodesia, 18 from the Colonial Empire, and 1 from the Anglo-Egyptian Sudan. There were three guests, the Director of the Forest Products Laboratory, Madison, Wisconsin, U.S.A., and two of the staff of the Forestry Branch of the Food and Agriculture Organization of the United Nations.

The Conference was a definite success. All difficulties of accommodation, travelling, rationing, &c., were overcome, much useful work was done, and extensive tours were made to the forests of England and Scotland. For this success, great credit is due to the Forestry Commission of Great Britain and its Chairman, Lord Robinson, who was also Chairman of the Conference.

An excellent Summary Report of the Conference is available from H.M. Stationery Office, London, at one shilling. It is reviewed later in this number of *Forestry*. Attention is invited also to the account of the Conference in the *Empire Forestry Review*, vol. xxvi, no. 2, 1947.

The hospitality of the Forestry Commission in their State forests and establishments was matched by that of private woodland owners, particularly the Duke of Buccleuch and the Earl of Moray, in their forests and homes. The Forest Products Research Laboratory, Princes Risborough, provided for the special interests of the forest products delegates, including tours and visits to factories and mills. The Imperial Forestry Institute, Oxford, entertained the delegates, and certain sessions of the Conference were held at Oxford. In addition to much hospitality in London the delegates were given a specially warm welcome in Edinburgh, Inverness, and the small village of Avoch in Ross-shire, which those who were present are unlikely to forget.

The value of freedom of speech and argument between competing interests was plain in many of the discussions, and especially when the Chairman deliberately provoked strong views on the principle of sustained yield working of forests. It is a pity that their position as guests induced the visiting foresters to withhold some of their constructive criticism of British forestry in the formal discussions. It would have been valuable to have on record their frank opinions on such British problems as the following, which became plain during the tours and informal discussions.

1. The afforestation of areas long bare of trees has far outstripped the replanting of woods felled since 1914. What can be done to accelerate the latter, in view of superior soil and situation? (Private ownership, low returns, high costs, rural housing, &c., affect the issue, and many acres of good forest soil are idle.)

2. The value of deep ploughing in strips or belts has been demonstrated in the early stages of afforestation of difficult ground. What will be the effect of such ploughing on the health and stability of the trees as they mature? Would complete ploughing, or shallow ploughing where that is enough, be better?
3. Are the current precautions against epidemic diseases adequate, in view of the large blocks of pure or semi-pure woods being planted? Permanent mixtures of species are difficult to form, but can the current research and planning directed against diseases be accelerated as an insurance demanded by the values involved?
4. In view of high labour costs, what can be done to quicken and increase the yield per acre of conifers without losing more on quality, financially, than can be gained on quantity? (Initial spacing, formation of canopy, thinning, pruning, intermediate and final returns, effect of rate of growth on value of timber, &c., are involved.)
5. Great Britain is falling behind Scandinavia, the U.S.A., and other countries in the use of modern genetics in forestry. The heavy British planting programme makes the leeway particularly regrettable. What can be done to put this right?

An important innovation at this Fifth Conference was the holding at times of separate discussions on forest products under the Chairmanship of Dr. F. Y. Henderson, Director of Forest Products Research, Princes Risborough, who was also a Vice-Chairman of the main Conference. Some forestry delegates attended these separate forest products meetings, and in all the more important main Conference meetings the chief forest products delegates took part. This interlocking is admirable, for each of these two main branches is vital to the other. The contribution of Mr. Hunt, Director of the Forest Products Laboratory, Madison, U.S.A., was particularly valuable, both to the special meetings on forest products and to the main Conference.

A standing Forest Products Committee was set up and it was recommended that forest products delegates to the next British Empire Forestry Conference should assemble for a time before its official opening. This idea might well be applied to tropical forestry delegates, for they have many special problems in common, problems of little or no immediate concern to foresters of the temperate zones. It would increase the value of these meetings to those from the tropics who travel far to attend and find much of their time together occupied by temperate forestry. Conversely it would avoid spending too much of the time of the main Conference on tropical problems.

The current political developments in India and Burma mark the passing of the Indian Forest Service which is being disbanded after 90 years of devoted service to forestry in India, Burma, and many other parts of the Empire. The following tribute was paid in a resolution passed with acclamation:

> 'The Fifth British Empire Forestry Conference, assembled at Oxford, desires to express to the present and past members of the India and Burma Forest Services its appreciation of the great services rendered by them to forestry in the territories under their charge and in the British Empire at large; and the Conference requests Mr. A. P. F. Hamilton, Inspector General of Forests for India, and Mr. D. J. Atkinson, Chief Conservator, Burma Forest Department, to convey this message to all concerned.'

In acknowledging the resolution on behalf of the Indian personnel of the For est Service Mr. Vahid (Hyderabad) spoke of the well-managed forest estate and the forest service with a fine tradition which Britain had given to India.

The address of the Chairman, Lord Robinson, delivered at Oxford, included a summary of the achievements of the Empire Forestry Conferences to date. He paid tribute to the valuable work of the Imperial Forestry Institute, Oxford, and the Empire Forestry Asso-

ciation, London, both children of the Empire Forestry Conferences, and appealed for benefactors to endow them adequately with a sum of £100,000. Those who know their work and value will endorse this appeal. The endowment would be a fitting memorial to the Indian Forest Service which has been so intimately associated with the Institute and the Association for which the appeal is made.

Mr. W. L. Taylor makes the following reply to Mr. W. E. Hiley's article at p. 137.

My article, to which Mr. Hiley refers, was in the nature of a *ballon d'essai* and I welcome his riposte. He very ably restates the conventional argument in forest finance but does not dissipate the 'confused thinking' which, he tells us, has led to departures from convention meriting discipline not unlike that which compound interest itself imposes. Both rates of interest and timber prices change as time passes. Surely such factors, alone, tend to make calculation at compound interest meaningless in long-term operations such as forestry? Moreover, it must be accepted that expended capital, however safeguarded, is apt to *wear out* and lose its efficiency in long-term conditions. Mr. Hiley says that compound interest is 'a useful method of working', but I continue to pose the question: Is it right and proper that the theory of forest finance be so shackled? The imponderables also remain with us.

W. L. T.

AN EXTRACT FROM *The Forestry Chronicle*, Vol. XXIII, No. 3, September 1947, pp. 199–200. (Canadian Society of Forest Engineers.)

(The following extract is reproduced with grateful acknowledgements to the journal and editor concerned.)

EDITORIAL

MAJOR-GENERAL HOWARD KENNEDY and his associates are to be congratulated. Through the medium of the Report of the Ontario Royal Commission on Forestry, just published, they have made an outstanding contribution to the cause of forestry—not only in Ontario but throughout the whole of Canada. For it is significant that many of the basic ills, irregularities, anomalies, and inconsistencies analysed with such acuteness and clarity throughout the 196 pages of this report are national rather than merely provincial in scope, and it is devoutly to be hoped that, not only will most of these recommendations be implemented by the Government of Ontario, but that throughout other parts of Canada corresponding progressive reforms will be undertaken.

A feature of this report is its inclusiveness and balance—'it was realized at the outset that the narrow concept of forestry, namely the growing of trees and the removal of wood products in various forms, has influenced the public viewpoint to the almost total exclusion of the other very important functions which the forests must perform in the national development of the social and economic life of the Province'. It is a sad fact that the enthusiasm of specialists in the field of forestry sometimes has tended to spotlight branches rather than roots, and that many misconceptions of forestry are the direct result of well-meaning but too narrowly defined enthusiasm. We do not deprecate such enthusiasms, but we do feel that they must be harnessed and fitted into the picture as a whole with exactly the right amount of emphasis.

We, as foresters collectively, have made a spectacular failure in providing the correlated, sustained, and complete story of forestry to the public. This is recognized throughout the Kennedy report and especially in the recommendation that Education and Publicity be raised to the status of a division in the Ontario Department of Lands and Forests.

Nevertheless—so vital is the necessity of creating public understanding and 'push' in respect to forestry—that we would have wished a more exhaustive treatment of this subject. The need is recognizable, but additional new techniques will have to be developed; and we cannot believe that there will be any real progress until all the complex factors have been thoroughly analysed, new procedures indicated, and a method of raising adequate finances suggested.

Forest education is treated in this same chapter but here again a more critical and searching analysis might have been expected—a statement of the basic problems with suggestions for remedial, corrective, or adjusting action. The dangers of too little and too much standardization; the advantages of reciprocal educational arrangements between agriculture, engineering, and forestry undergraduates; the further development of post-graduate courses; the need for specialization and the equal need for a broad general education in the humanities; the tremendous field (potentially far more important than any probable adjustments in text-books) for the introduction of forestry into secondary schools through the medium of vocational guidance and counselling by duly appointed representatives of the profession in different school districts—all these, and other items, might have been profitably stressed. Perhaps this criticism is unfair as by inclination and interest we may be prejudiced in the direction of forest education. Nevertheless, the forest schools are the recruiting stations for the profession, and any review of cause and effect in the forest industries should be inclusive of the status, responsibilities, and opportunities of our educational establishments.

There are outstanding chapters on woodlots, timber measurement, and fire protection; and among the more interesting recommendations are that cubic measurement be substituted for the unscientific Doyle Rule; that the cutting of out-size pulpwood (i.e. over 4 feet in length) be forbidden; and that a Marketing Division be created within the Department of Lands and Forests for the purpose of aiding owners of woodlots to dispose of their products on the most profitable market.

We specially commend the lack of discrimination in favour of any group of wood-using industries. It is constantly underlined and restated that forest management in its ultimate and truest sense is impossible of attainment as long as there are single-purpose operations in the woods. As a corrective measure it is recommended that twelve forest operating companies be formed in Ontario, and that all operations in the woods be undertaken on an over-all basis solely by these companies. No doubt this recommendation, the most radical and far-reaching in the report, will be hotly debated. However, if a reform is a reform, it is radical; and if it is radical, it is controversial. Some of the greatest reforms have been the most bitterly contested, and perhaps this will be one of these. We would suggest, however, that as an adjunct to this proposed plan a special Board might be created to co-ordinate the allocations and decisions of the twelve companies on a province-wide basis. This is a specialist job, and one which the suggested Advisory Committee to the Minister would have neither the time nor experience to cope with effectively.

This report, profusely illustrated and beautifully presented and edited, has obviously been motivated by a high sense of public duty. It should be a reading 'must' for all foresters.

Also, we would like to think that one of the first responsibilities of the new Division of Education and Publicity would be to break this report down and serve it continuously to the public in such manner that it will be thoroughly discussed and understood.

K. G. F.

REVIEWS

Breaking New Ground. By Gifford Pinchot. Hardcourt, Brace Publishing Company, New York, 1947. Price 26*s.* 6*d.*

Review by G. B. Ryle

As every forester has to divide his time between his woods which he loves and his office which he abhors, so Pinchot, in this autobiography of his twenty-one years of learning forestry and of creating the U.S. Forest Service, flits lightsomely from his office to the White House, and thence to the backwoods, with a freshness which makes one feel his zest about them all. A disciple of Dr. Brandis and a product of Yale and of the Nancy Forest School, Pinchot returned to America with a complete determination to bring forestry into the U.S. forests and with but the flimsiest conception how to set about it. His early struggles and then his overwhelming wave of success, his constant battling against the combined viciousness of big money and dirty politics, and the mutual help between President Theodore Roosevelt and himself because they both preferred the wilds to Washington make good reading. So do his ideas on the construction and the corporate spirit of the Forest Service which he brought into being, and so do his incessant campaigns to win over the people of the United States, the settler, the trapper, the landowner, the merchant prince, and the politician, from the previous policy of devastation and get-rich-quick to a policy of conservation.

Pinchot's administrative system may be gathered from a random selection of his guiding principles in the employment of his new staff and of the staff he had to take over from the Land Office. Give a man his head and let him use it. Nothing destroys the morale of a service more certainly than retaining known failures, even if they be elevated to harmless sinecure posts. Wherever possible fill vacancies by internal promotions instead of importing new blood. Office and field must be united by intelligence, not by red tape. Wherever differences of opinion crop up between field and office, the field-man's recommendation should be adopted unless there is strong reason against it. Pick your man for his ability, not for the sake of his relatives and certainly not for the sake of his political friends. The reliability of a Forest Service is rooted in its personnel and in its *esprit de corps*. All these may sound truisms, but in America at the beginning of this century many of them were strange: many of them created hostility, but the hostility came from outside the service, not from within its ranks.

Had Roosevelt's term of office been longer or had his successor, Taft, also been a woodsman, the natural development from forest conservation to the conservation of the whole of the natural resources of America, land, water, water-power, and minerals, would have followed immediately. Had Taft followed Roosevelt's conservation policy as he had pledged himself to do, it would not have fallen to the lot of an unknown 26-year-old Forest Ranger to expose the Ballinger–Cunningham scandals and to get himself fired for doing so. Gifford Pinchot would not have been sacked. The World Conservation Conference might have taken place at The Hague before 1914 instead of maybe in 1948. The First World War and the Second World War might have been avoided.

Pinchot undoubtedly had a bee in his bonnet about conservation and it buzzed louder at every dam of political or money opposition he encountered. The forests and the other natural resources of America were, he considered, the property of the people of America for all time, not just of the monied few, to be squandered at their will.

I found this book under my family Christmas tree and I thoroughly enjoyed my Christmas holiday, but I shall not forsake forestry for politics. It takes a *very* big man to do both, but Pinchot nearly succeeded.

The Earth's Face (*Landscape and its relation to the health of the soil*). By Ehrenfried Pfeiffer. (With an introduction by Sir George Stapledon.) Faber and Faber, London, 1947. Price 12*s*. 6*d*.

Review by Sir Harold Glover

IN a virgin country, such as was America not so very long ago, Nature preserves a wonderful balance. Conditions are stable and there is no erosion of the soil. The landscape is what the author calls 'healthy'. Man has disturbed the balance by cultivating cheaply and extensively with the help of tractors vast stretches of grass and forest land, thereby exposing the surface soil to the erosive actions of wind and water.

The fertility of the soil is confined to its upper layers where it is renewed by the annual decay of vegetation and by the numerous micro-organisms, worms, and insects which make up the soil fauna. Once the upper layers of the soil have been removed the sub-soil is infertile and remains so until humus has again been restored. Corn crops exhaust the soil, and fertility can be maintained only by mixed farming, the growth of leguminous crops, and the use of animal manure.

Industrialism has hastened the process of degradation, particularly the clear felling of vast stretches of forest and the ploughing of natural grass lands. Nature has taken a terrible revenge, and the destructive floods of the Mississippi and the 'dust bowl' are direct consequences of the destruction of the vegetation which until recently held the soil in place.

The author takes us from place to place with bewildering rapidity, from the east to the west and from the Old World to the New, finding much to admire in the stable landscapes of Switzerland and in the thousand-year cultivation of central France and elsewhere.

He deplores the haphazard growth of the towns and would like to see open parks instead of artificial municipal gardens. He would like industries to be established in the country where workers could spend their spare time in rural surroundings which would improve morale and spiritual values.

So far we can accompany him: but some of his arguments are unscientific, particularly when he quotes from ancient mythology. Nevertheless, the author's conclusions are sound, as are the suggestions he makes for bringing home to the public and to planning authorities the need for maintaining a 'healthy' landscape and thereby ensuring a stable environment. There is no doubt whatever that the Earth will get poorer and poorer until all nations and people practise a stable agriculture and base all cultivation and pastoral and forestry practices on the continued maintenance of soil productivity and fertility, particularly in the hills where retribution follows quickly on the misuse of natural resources.

The sixty excellent photographs with their useful captions could hardly be improved upon and add greatly to the value of the book.

Handbook of the Trees of the Northern States and Canada. By Romeyn B. Hough. The Macmillan Company, New York, 1947. Price 28*s*.

Review by F. K. Makins

SO many North American trees thrive in Britain that any book on this subject attracts the attention of the British forester. At first glance the title of this one is somewhat misleading, for the large and rich territory west of the Rocky Mountains is omitted. Thus

there is no mention of Douglas fir, Sitka spruce, the Sequoias, Western hemlock, and so on. Again, species such as live oak, soapberry, loblolly bay, and osage orange are hardy only in the extreme south, but a note on page 1 further defines the region as 'lying north of the northern boundaries of North Carolina, Tennessee, Arkansas and Oklahoma and east of the Rocky Mountains, and extending southward in the Appalachian region to Northern Alabama and Georgia'. The author's claim to have included 'practically all the well-defined species within the area indicated' cannot, however, be substantiated. *Crataegus*, in which the region is very rich, is limited to nine species, including our own hawthorn. Other strange omissions are those of *Aesculus discolor*, conspicuous on account of its large panicles of brick-red flowers; the pink-fruited *Acer grandidentatum*; the white alder (*Clethra acuminata*); *Halesia monticola*, larger and more vigorous than the included *H. carolina*; nutmeg hickory (*Carya myristiciformis*); the grey and smooth alders (*Alnus incana* and *A. rugosa*); chestnut oak (*Quercus montana*); and Carolina poplar (*Populus angulata*). It may be objected that some of these are more shrubs than trees, but if *Leitneria floridana*, which the author admits does not exceed 20 feet in height, is included, he cannot justify the omission of much commoner and more conspicuous species on this ground. It is impossible to draw any line between trees and shrubs, and this is a defect of the book. *Magnolia grandiflora* is also omitted, presumably because it is not hardy in the region.

The book was first published in 1907 and has been reprinted without any attempt to bring the botanical names up to date.

At the beginning there is a key to the families, based mainly on flowers. At the end are keys to the genera, based on various characters, the choice of which is original and good. While the difficulty of compiling the keys has been reduced by omitting so many species, their value is reduced in proportion.

The chief merit—in fact, the only important part of the book—is in the photographic illustrations. Each species illustrated (there are 208 in all) occupies two opposite pages. On the left-hand page the leaves, twigs, and fruits (not the flowers) are admirably spaced on a background of 1-inch squares, the detail being almost as good as in a careful line drawing. On the right-hand page is a photograph of the trunk showing a foot-rule placed horizontally against it, a small map showing the distribution of the species, and often a microscopic section of the timber. Space is also found for a description in writing, which deals not only with botanical characters but with matters of economic and general interest. Though there is no conscious striving for artistic effect these pages are in fact works of art, and in producing them the author has made a valuable contribution to our knowledge of North American trees.

Timber, its Structure and Properties. By H. E. Desch. Second edition. Macmillan & Co. Ltd., London, 1947. xxii+299 pp.; 55 pls.; 45 figs. Price 18*s.* net.

Review by B. J. Rendle

THIS is one of the few general text-books on wood technology published in this country. The appearance of a completely revised and considerably enlarged edition is timely, as technical education on timber is in the ascendant and teaching material of all kinds is scarce. In the preface to this second edition of his book, first published in 1937, the author refers to the startling progress that has taken place since then in the field of wood technology. Between the two world wars an immense amount of data on the basic properties and treatment of timber was collected. There has followed a period of development, due in part to the strategic importance of timber as a constructional material for

war purposes and also to the dire necessity for economy in the use of timber generally. With the aid of modern scientific methods, basic technical data have been applied to many practical problems of utilization, so that timber is being used more scientifically and more economically than ever before.

A criticism of the first edition (*Forestry*, vol. xii, no. 1, 1938, p. 48) was that the author devoted too much space to describing the basic properties of timber and methods of investigation, and too little to their application. This second edition is more practical. A special chapter is devoted to the use of timber as an engineering material; there are new sections, among others, on stress-grading, timber-connectors, adhesives, the economic aspects of wood preservation, and the toxicity, penetration, and performance of wood preservatives. The chapter on seasoning is double its original length. Oddly enough, plywood is dealt with only briefly under the heading of 'Adhesives'.

The main purpose of a text-book is to summarize existing knowledge. In this case the author has certainly brought together a great deal of information which is not readily available except in a few special libraries. The critical student, wishing to pursue the matter farther, may complain that Dr. Desch does not always cite references in support of his statements. Admittedly the reader will generally be able to locate the original source of information by referring to the bibliography at the end of the book, but in certain cases the citation of literature references in the text would be an advantage.

The author's experience of timber has mainly been acquired abroad, as is apparent from the fact that many of the timbers referred to in the text are virtually unknown in this country. This is a weakness in a book designed for the enlightenment of architects, surveyors, and building contractors. The author's personal interest in the microscopic structure of wood is reflected in the rather detailed treatment of this subject.

Decay of Timber and its Prevention. By K. St. G. Cartwright and W. P. K. Findlay. H.M.S.O., London, 1946. vi+294 pp. Price 12*s.* 6*d.*

Review by W. R. Day

ALL those connected with forestry or forest products have long been aware of the very great lack of text-books covering the aspects of silviculture, forest utilization, and wood manufactures with which fungi are concerned. This is particularly true of Great Britain, where hitherto no work has been published which deals adequately with the mycological side of forestry or the utilization of timber. The book under review satisfactorily removes this deficiency in relation to fungi as causes of decay in converted timber. Like most well-constructed books of its type, it is the result of a long period of preparation; a period marked by the appearance, between 1936 and 1942, of the admirable descriptions of the principal decays affecting oak, softwoods, and hardwoods which this volume collects together and extends.

The book sets out to deal primarily with fungi as causes of decay or staining in timber as material for economic use. It falls effectively into several portions. There are five preliminary chapters in which the causes of decay are described; the mycological technique of examining and preparing cultures from decayed wood is dealt with; and the physiology of wood-destroying fungi and the effects of decay on wood are discussed. There is much in these chapters of general interest, but they are largely written for mycologists investigating wood decay.

Following these chapters are four in which are described, first, the principal decays of standing trees, both conifers and broad-leaved; second, rots of felled timber and timber in

service in the open; and third, rots of timber in buildings and structures. The principal fungi listed are dealt with seriatim and in a similar manner. The botanical name and the synonymy of the species are stated, together with any known common name; the region of its occurrence is given; its sporophore, the type of rot it causes, and its manner of growth in culture are described; its economic importance and, where they exist, any physiological data regarding the growth of the species are also discussed. Summarizing discussions are given, appropriate to the chapter, on general measures of prevention. This section of the book contains a number of excellent illustrations. An interesting and most useful feature is the presenting in tabular form of the diagnostic characters of the principal species of fungus. The authors are to be congratulated on this systematic and easily consulted method of presentation of information: it should greatly facilitate the recognition of species.

The chapters just discussed form that part of the book which is devoted to systematic description. The next three are concerned with the development of decay under particular conditions of use, the reasons for this, and the general sanitary measures which are necessary for its control. There are three sections: the first deals with decay of timber in storage and transport; the second with its decay under various conditions of use, as in mines, vehicles, ships, buildings, and so on; the last with the deterioration of manufactured wood products such as plywood, pulp, and wall-boards. This is the part of the book which, perhaps, will appeal most to the practical man. The discussions are clear and easily read. Where, as is inevitable in a book of this size, they are summaries of an extensive subject, adequate references are given for those who wish to carry their studies farther.

There are three concluding chapters. The first deals with the natural durability of timber. The details are presented clearly, so that the reader appreciates quickly the types and the results of the differences in character which occur. In the next the preservation of wood by chemical treatment is discussed summarily but efficiently; and finally there is a chapter concerned with the staining and discoloration of timber. These are big subjects in themselves and necessarily receive short and summary treatment. Again, however, adequate references are given for those who need to study further, and the presentation of detail is clear, as always in this book. The chapter dealing with chemical preservatives also describes laboratory methods for testing their efficiency; and in an appendix the wood-block method of test for the toxicity of wood preservatives to fungi is given.

This is a well-produced book, written and constructed with the convenience of the reader continually in mind. It is provided with an index, and at the end of each chapter a list is given of the works referred to therein. The index is useful but not complete; the items in it refer to sections in the book rather than the particular places in the book in which a particular subject is mentioned; for example, a species of tree is referred to only when a section is devoted to it, so that if mention is made of a tree only in the course of a discussion, as with noble fir and persimmon, there is no corresponding reference in the index. Some amendment of this might well be made in a future edition.

This is a work which necessarily has limitations, and considering the range of subjects this is no disadvantage: it does, in fact, keep it to a reasonable and digestible size. The book is not, however, a complete work of reference to the fungi in Britain which cause decay of wood; it merely refers to principal and important species. It does not, except in the most summary manner, refer to the role of the fungi which cause decay, in the development of disease in living trees: it does, however, describe them and the decay which they cause in such trees. Similarly it does not give detailed descriptions of technical processes, as, for example, in the case of the chemical preservation of wood. The selection of field which this implies has been carried out wisely, and references are given for the benefit of those who wish to extend the field of their study.

There are few criticisms to make of this work. In the subjects covered by the first part of the book, with which the reviewer is best acquainted, a number of suggestions may be made. Simple illustrations, or diagrams, of the structure of wood would make much of the discussion of greater interest and use for many people. Occasionally it would be an advantage to define the meaning of a term used, e.g. the use of 'parasite' for the saprophytic fungi which live ordinarily within the standing and living tree but may live only on its dead inner tissues. Such organisms cause disease in that they decay the mechanical structure which holds up the tree; but it is necessary to realize that in the case of a tree, which contains within its body so much dead tissue, a fungus need not be a parasite, in the sense of an organism which attacks the living body, in order to cause disease. In the section which deals with the chemistry and microscopic structure of wood it would be an advantage to have some definition of such terms as 'cellulose lattice', 'chain molecules', and 'fibril', which without explanation will probably mean very little to many readers. Occasionally references to previous work might well be extended: for example, in the case of *Trametes pini* references to the economic importance of this fungus in Europe as well as in North America would have been of interest. These are, however, small matters and should not detract from our gratitude for a most useful work and a notable addition to the literature of applied mycology.

Über die Physiologie ligninabbauender Bodenhymenomyzeten. Studien an schwedischen Marasmius-Arten. By Gösta Lindeberg. Symbolae Botanicae Upsalienses, VIII. 2. Uppsala, 1944. Pp. 183.

Review by Ida Levisohn

THIS is a welcome contribution to our scanty knowledge of the activity of the litter-decomposing hymenomycetes, in particular their effect on the lignin, cellulose, and furfural-yielding components of litter, and their nutrient requirements as studied in synthetic cultures.

Fourteen species of *Marasmius*, common in Swedish forests, were used to test four types of litter: pine-needles, beech leaves, aspen leaves, and straw derived from *Glyceria maxima*. The autoclaved litter substrates supported the growth of all *Marasmius* species investigated. Analyses of the litter media at the beginning and end of the experiments showed that all these species of *Marasmius*, with the exception of *M. chordalis*, decompose lignin to a considerable extent, the most effective decomposition being brought about by *M. alliaceus*. Likewise, all the species of *Marasmius* tested are able to decompose the cellulose and the furfural-yielding substances of the litter material. The survey of the ratio per cent. lignin decomposed/per cent. cellulose decomposed for various types of litter, recorded in Table 13, p. 35, appears to be of particular interest in relation to the wider problem of humus formation, especially in connexion with the line of investigation taken up by R. Falck on 'Humusbildung' and 'Humuszehrung'; and may indicate the important role that certain species of *Marasmius* play in litter decomposition in deciduous and coniferous woods. Although, as Lindeberg points out, the controlled conditions of the experiments differ considerably from the natural conditions under which various factors determine the activity of the soil hymenomycetes, one is justified in assuming that the species of *Marasmius* discussed here—and probably other species of the same genus—play an essential part in the formation of humus in woodlands. In a later publication Lindeberg lists a number of other litter-decomposing hymenomycetes, e.g. species of *Clitocybe*, *Collybia*, *Lepiota*, and *Mycena*, which possess the power to decompose lignin and cellulose ('Thiamin and Growth of Litter-decomposing Hymenomycetes', *Bot. Notiser*, i, 1946, pp. 89–93).

Thus the litter-decomposing hymenomycetes as an ecological group show a behaviour similar to that of the ecological groups formed by the typical wood-destroying hymenomycetes and the coprophilous hymenomycetes, both of which decompose lignin and cellulose.

The section of Lindeberg's research dealing with the growth conditions of *Marasmius* in synthetic culture media occupies the larger part of the present study and is concerned with investigations of growth reactions as affected by various sources of C and N, by a number of growth substances, by the pH values of the media, and by the presence of certain metallic ions. With regard to N assimilation Lindeberg found that all species of *Marasmius* tested utilize NH_3 nitrogen as well as organic nitrogen; only *M. fulvobulbillosus* assimilates NO_3 nitrogen. This is of interest in connexion with Hesselman's investigations which demonstrate that in Swedish forest litter nitrates are present only in negligible amounts.

The influence of growth substances is the subject of an intensive study by Lindeberg. It was proved that all species of *Marasmius* tested are heterotrophic for thiamin, and that for one of the species, *M. androsaceus*, biotin is a limiting factor for growth. The later publication by Lindeberg, already cited, reports observations that other litter-decomposing hymenomycetes, namely, species of *Clitocybe*, *Collybia*, and *Mycena*, are also heterotrophic for thiamin (ibid.), and *Collybia dryophila* is recorded as being heterotrophic for both thiamin and biotin (*Svensk Bot. Tids.* xl. 1, 1946).

Among the metallic elements the effects of Al, Ca, Cu, Mn, and Zn were tested on a number of species of *Marasmius*. It was found that a pronounced stimulatory effect is produced by Ca and Mn. Cu and Al favour growth of the mycelia to a slight degree only. Zn was proved to be a limiting factor for the growth of *M. scorodonius*. The other species of *Marasmius* tested are favourably influenced in their development by Zn ions added to the culture media, but to what extent the growth of these mycelia is dependent on the presence of Zn requires further investigation.

It would be of interest to know how the metallic elements in question influence the growth of *Marasmius* and other litter-decomposing fungi under natural conditions. Lindeberg assumes that these metallic elements are present in forest litter and that they play a part in the favourable effects on growth of *Marasmius* produced by an extract of aspen litter. It is regrettable that chemical analyses of the ash of the litter materials were not undertaken and that there are no data available on the presence of these metals which stimulate a number of litter-decomposing hymenomycetes.

Der Einfluss von Waldstreuextrakten auf das Wachstum von Bodenpilzen, mit besonderer Berücksichtigung der Wurzelpilze von Bäumen. By Elias Melin. Symbolae Botanicae Upsalienses, VIII. 3. Uppsala, 1946. Pp. 116.

Review by Ida Levisohn

IT appears to be generally accepted that 'sterilized' humus is not a suitable medium for growing mycorrhizal fungi of trees. Melin, during his classic researches on mycorrhiza-formers, found that the types of humus from Sweden he tested supported growth of the mycelia only when the soil was leached after sterilizing (steaming) and, even then, growth was very weak.

Recent experiments with various heath and woodland soils of this country have shown that no leaching is required after the soil has been steamed in a certain way and that a number of typical mycorrhizal fungi grow quite satisfactorily on such soil media (M. C. Rayner and Ida Levisohn, unpublished).

Melin apparently expected forest litter to behave similarly to humus media, as his present paper starts with the inquiry: 'The experiments published here were designed first of all to investigate whether the litter of our deciduous and coniferous woods exercises an antibiotic effect on the mycorrhizal fungi of trees' ('Die hier veröffentlichten Versuche sollten zunächst ermitteln, ob die Laub- und Nadelstreuarten unserer Wälder eine antibiotische Wirkung auf die Mykorrhizapilze der Bäume ausüben'). Indeed, it would have been of interest to know how the mycorrhizal fungi behave on 'sterilized' litter. Melin, however, deals with litter extracts (cf. title of paper), and apart from a small number of experiments with litter residues after extraction he does not put on record experiments with the litter itself.

The litter extracts tested were prepared from broad-leaved trees (i.e. maple, beech, birch, aspen, elm), from pines, and from straw derived from *Glyceria maxima*. A number of hymenomycetes and gasteromycetes known to be mycorrhiza-formers of trees (e.g. species of *Boletus*, *Lactarius*, *Rhizopogon*) were the main subject of the investigations. *Mycelium radicis atrovirens*, a very widespread pseudomycorrhiza-former, and various saprophytic soil fungi (e.g. *Morchella conica*, *Psalliota arvensis*, species of *Clavaria* and *Clitocybe*) were likewise tested. For the purpose of comparison *Phycomyces blakesleeanus* was used.

The test media were prepared by adding various amounts of the litter extracts to a synthetic nutrient solution containing thiamin, in the case of mycelia which had proved to be heterotrophic for thiamin.

It was found that diluted litter extracts—cold- as well as hot-water extracts—favour growth of the mycelia investigated. However, only when the extracts are used within the limits of a certain low concentration is the stimulatory effect produced. Higher concentrations of these extracts exhibit an 'antibiotic' effect, either inhibiting or preventing growth of the mycelia. Toxic effects were produced by extracts from all the types of litter tested with the exception of that from straw derived from *Glyceria maxima*.

In most cases, the inhibitory system was increased by autoclaving, whereas sterilization through a Seitz filter did not influence the antibiotic substance. Autoclaving apparently increases the toxic activity by adding new growth-inhibiting substances (*β Hemmungsstoffe*) to those already present in the 'natural' material (*α Hemmungsstoffe*). The effect of autoclaving is particularly pronounced in maple extract and hardly noticeable in extract from aspen litter. The mycorrhizal fungi were found to be more sensitive to the α system (*α Hemmungsstoffe*) than any of the other types of fungi tested.

As regards the stimulatory system, circumstantial evidence suggests that the litter extracts tested—apart from growth-promoting substances like thiamin and biotin—contain other growth substances identical with Robbins's factor Z (described as present in a number of organic materials like potato, agar, and peptone, and also found in the mycelium of *Phycomyces*). Melin arrives at the conclusion that these growth substances are partly responsible for the stimulation of the mycelial growth as affected by the litter extracts under investigation. One hopes that the Swedish School under the guidance of Professor Melin will continue to work on these lines in order to throw light on the complex problem of fungal nutrition, in particular the growth requirements of mycorrhizal fungi. At present the nature of factor Z is not known, and for this reason conclusions as to its effects on fungal growth are not likely to be accepted without criticism.

Fifth British Empire Forestry Conference. Great Britain, 1947. Summary Report, Resolutions and Reports of Committees. London: H.M. Stationery Office. 1947. 1*s.* net.

Review by the Editor

THE compilers of this excellent summary are to be congratulated on their clarity and brevity. The field covered by the Conference was very wide and it worked hard. The summary achieves in fifty-six pages a record of all the delegates, papers presented, tours made, the reports of six technical committees, and the resolutions; and a useful outline of the main discussions. This Summary Report should be read by all who are concerned with forests or forest products in any part of the world. Those who are citizens of the British Empire can read it with legitimate pride but not with any complacency. It is plain that in many parts of the Empire there is urgent need of more action on behalf of forests and forest soils, to quicken survey and protection, to use the tree crops rationally and efficiently, and to improve and increase them.

The Fifth Conference was notable in that forest products were given a special and proper place in the proceedings and in the plans for future conferences. The consumer is as important as the producer. Each is essential to the other. It is a good sign that in addition to forest products research the timber trade was well represented at the Conference. It was also fitting that the U.S.A. was represented by a very welcome guest, Mr. Hunt, Director, Forest Products Laboratory, Madison, whose knowledge and personality were a great asset and symbol.

Time was taken, in spite of a very full programme, to welcome at one of the Oxford sessions two guests from the Division of Forestry and Forest Products of the Food and Agriculture Organization of the United Nations, to hear an outline of their plans, and to promise all possible assistance. The statistics already collected from the forests of the British Empire are available as a substantial contribution to F.A.O.'s wider aim of compiling vital data for the forests of the whole world.

If possible, the Summary Report under review should be read along with the editorial notes and article on the Conference in the *Empire Forestry Review*, vol. xxvi, no. 2, 1947. (Attention is invited also to the reference to the Conference in Society's and Other News at pp. 229-31 of this number of *Forestry*.)

A suggestion by the forest products delegates to the Conference, recorded at p. 48 of the Summary Report, that their successors should assemble for a time before the official opening of the next conference is noteworthy. Similar action in respect of tropical forestry delegates would allow them more time for special discussions of less direct interest to the foresters from temperate zones, and would ease the pressure on the time of future main conferences.

A résumé of the discussions of the main Conference occupies pp. 8–17 of the Summary Report. It is divided into Sections A, B, C, &c., which, however, do not correspond with the similar lettering of the technical committees. This is slightly confusing unless it is realized.

In the discussion on Land Utilization and Forest Policy it was rightly stressed that forest policy should be an integral part of the general land policy of the Government concerned, not just a departmental matter. It was held that sound management of private forests, where they were extensive, was an essential of a healthy policy; and that State reserves must be adequate to supply any requirements not met by private forests.

A session was devoted to paper pulp. Great possibilities were forecast for the exotic conifer plantations of New Zealand, Australia, and South Africa, and some pulpwood presently from the increasing areas of British plantations.

The dire results of the two world wars on the forests of the United Kingdom were described. Two-thirds of the standing timber existing in 1939 had been felled in 1939–45, mainly in private forests. 'As a result it had now been made clear to all that the nation could no longer afford to neglect woodlands, or to allow land suited for timber-growing to be left relatively unproductive.' The small size and scattered nature of the private forests were a difficulty in the way of systematic management, for often the plantations had been laid out as shelters, subsidiary to agriculture or other interests. Co-operative sharing of the services of a professional forester was mentioned.

The discussion on the technique of afforestation and rehabilitation of woodlands ranged widely. Ploughing, group planting in devastated woodlands, mycorrhizal fungi in forest nurseries, surprising results on small and large trees from traces of zinc salts, planting espacements, the *taungya* system of the tropics, &c., came into this discussion.

The sessions in which Research was considered were specially interesting. Ecology and genetics received much attention. In discussing the latter the Conference was helped by Messrs. Crane (John Innes Institute), Hudson (Imperial Bureau of Plant Breeding and Genetics), and Richards (Cambridge University). One view was that other research than genetics should have prior claim at present, owing to the long time before results were produced from genetics, the risk of acting on uncertain results, and the scarcity of experts. This view was rejected by the majority of the delegates, because modern technique overcame the obstacles mentioned and the probable results were held to be well worth securing. 'It was stressed that genetics and silviculture were not opposed but should be carried on on parallel lines. . . . Genetic research did not necessarily mean trying new species; the greater part of the work was concerned with improving species, the silviculture of which was well known. Several delegates gave examples of very valuable results that have been obtained from selection of race and from seed provenance.'

Research in timber technology produced a valuable discussion on conservation through better utilization, and the future of wood as a raw material. Mr. Hunt of the U.S.A. spoke on the versatility, easy fabrication, good strength–weight ratio, and aesthetic value of wood.

In discussing Education, especially during the Oxford sessions, the functions and value of the Imperial Forestry Institute and the Imperial Forestry Bureau, both of which are at Oxford, were explained and acknowledged. The role of the Forest Products Research Laboratory, Princes Risborough (which is some 20 miles from Oxford), in forestry education was recognized. So was the need for greater publicity for forestry, especially in timber trade circles which were powerful and vitally concerned.

The address delivered at Oxford by the Chairman of the Conference, Lord Robinson, was outstanding and is briefly summarized in the Report under review. He expressed dismay at the casual attention to Empire forestry at the highest levels, and appealed for £100,000 to endow the Imperial Forestry Institute and the Empire Forestry Association. His tribute to the Indian Forest Service at the end of its great career was moving. A special resolution on the subject was passed and is given in the Summary Report. It will be valued by the officers of that Service, whose *esprit de corps* was and still is very high. They were human and made mistakes, but they accomplished much of very great value in India, Burma, and elsewhere, especially in restoration and conservation.

In the discussions on Silviculture the unorthodox methods of wide spacing and heavy thinning introduced by Dr. Craib for exotic pines grown in South Africa were considered. Dr. Craib's own description of his technique was modest and persuasive. Mr. W. E. Hiley, who had just returned from a visit to South Africa, praised the results there, with

some reservations. The fact that pruning is an essential part of the technique is rightly recorded in the Summary Report. Whatever doubts foresters outside South Africa may have on the applicability of Dr. Craib's methods in their countries, his results merit at the very least careful consideration. Foresters and business men in South Africa appear convinced that there at least the results are admirable.

The necessity and value of even a simple Working Plan were urged by those with practical experience of managing large forest areas, including mature crops. They pointed out that plans need not be complicated and that they should be open to revision and alteration as experience and new factors demanded changes.

Protection against fire, insects, and fungi was discussed, but much more briefly, for lack of time, than its importance warranted.

The South African forest products delegate, Mr. M. H. Scott, gave an account of the work done there by Mr. J. M. Turnbull, and others, on the effect of age and rate of growth on the density and strength of exotic pines such as *Pinus radiata*, *P. patula*, &c., grown in South Africa. The subject is complex. The South African results and deductions differ from some of those arrived at in North America, and do not agree with firmly held opinions in Europe. The practical test of use during the recent war appears to show that fast-grown South African pine gives timber which is quite satisfactory for many purposes. It is of vital importance to Great Britain, with her heavy planting programme, to know what class of timber her fast-growing Sitka spruce (*Picea sitchensis*), Corsican pine (*P. nigra* var. *calabrica*), &c., are likely to yield, and to North America to know just how her second-growth Douglas fir (*Pseudotsuga taxifolia*), &c., will compare with the disappearing virgin timber, in actual quality, not merely prejudiced opinion.

The discussions on 'Empire Needs of Forest Products' and 'Survey of Resources' are outlined in the Report under review but are considered here under the reports of the Technical Committees who dealt with these subjects. Space permits only a very brief reference to some of the main points in the six committee reports reproduced in the Summary Report.

Committee on Land Use. Planning for all uses, not merely forestry, is commended. The need for vigorous education and publicity is stressed. It is thought that it will be necessary in some countries to adjust taxation and conditions of tenure in order to encourage private owners and lessees of Government forests to practise good forestry.

Committee on Forest Management, Silviculture, and Protection. The value of even simple Working Plans and of adequate records is recognized. Studies are commended in ecology, genetics, pruning, espacement and thinning, and soils and nutrition. The very great and growing importance of fire protection is very strongly stressed. In the matter of damage by fungi and insects, prevention rather than cure is commended, by studies prior to severe outbreaks, and by good forest management.

The menace of uncontrolled shifting cultivation (nomadic agriculture) to tropical forests is recognized, and the need for fighting this menace by lengthening the time between successive food crops, combining food production and forestry by the *taungya* system, &c. Uncontrolled grazing is also condemned as a major cause of deforestation and soil erosion. Rotational closure and the education of public opinion are suggested.

The same committee reports separately on *British Forestry*.

British Forestry. The report is brief and praises the efforts being made to restore and increase the British woodlands. It touches lightly on but does mention some major British problems to which satisfactory answers are still lacking. Thus—'it is desired to emphasise that forestry must not be relegated to the poorest land, in order that supplies of timber may be secured as early as possible'. And . . . 'it understands that many private

woods are not earning their keep and should be restored to full production as soon as possible'.

The report recommends further experiments on wider spacing and early thinning which have proved so potent in South Africa, with provision for live pruning.

The absence of Working Plans is noted and the question of forest records is mentioned.

Committee on Forest Products Research. Closer liaison between forestry and forest products is commended, and important practical steps to that end are suggested. The chief step recommended is the formation of a Forest Products Committee, as resolved at the Fourth British Empire Forestry Conference in 1935.

An important practical suggestion is that the forest products delegates to the next Empire Forestry Conference should assemble for a time before its official opening. This excellent idea would be very helpful if extended to tropical forestry delegates also, for they have special interests peculiar to their field.

Other major features of the report include the case for strengthening forest products laboratories on the economic side, the need for trained forest utilization officers in areas without adequate laboratory or experimental facilities, and the grouping of secondary timbers, especially in mixed tropical forests, by similar properties and uses.

Committee on Survey of Resources. The report recommends completion by the end of 1957 of a preliminary survey of all the forests of the Empire, largely by air survey. The cubic foot (under bark), true volume, is suggested as the unit of measurement for standing timber, in preference to board foot scales with discounts for milling waste varying with girth, or the Hoppus system with its fixed discount of 21½ per cent.

It is suggested that a Technical Committee on air survey of forests, with a permanent Secretary, be set up by His Majesty's Government in the United Kingdom, in consultation with the other Governments of the Commonwealth, to advise on and co-ordinate the whole survey programme. A scale of 2 inches to the mile (1 in 30,000) is believed to be an adequate minimum. The allotment of special officers from each Forest Department to interpret air photographs is very rightly recommended, for otherwise the full value of the survey cannot be reaped.

Committee on Education. It is noticeable that not one of the four Professors of Forestry of the four university schools in the United Kingdom was a member of this Committee or signed the report. Their views on it would be interesting and valuable.

Some of the recommendations with which practical foresters are likely to agree are on the value of cadet service as a guide to selection of potential forest officers for training; on the need for proper staff and equipment in any school for forest officers, including instructors with field experience; and on ruling out post-graduate students as instructors, except in specialist subjects, until they have had practical experience in the field as successful working forest officers.

Good and progressive recommendations are that forest exploiting agencies, whether State or private, should be given opportunities to train their staff in forestry; that more should be taught about land acquisition and management, tenure, tenancy, and the social results of good or bad forestry; and that all ranks should be eligible for promotion on merit to the officer grades by a professional qualifying course on a scholarship basis.

Committee on Timber Supply. (*Empire Needs of Forest Products.*) The field allotted to this Committee was wide and difficult, especially with political and economic factors so unpredictable as they are at present. Their report confirms in general the conclusions of the Food and Agriculture Organization of the United Nations on the acute world shortage of wood, especially sawn timber. The Committee complains of the lack of data and information for accurate estimates, as opposed to broad conclusions. They recommend

fuller utilization of stands by better integration of industries such as pulping and sawmilling, by the study of end uses, by attention to secondary species, and by avoiding unnecessarily strict specifications which date back to buyer-market conditions.

They subscribe firmly to the principle of the sustained yield, but recommend regulated over-cutting for the next five years, provided it is accompanied by increased protection and later correction by working plan revision.

The formal resolutions were based on the discussions and reports summarized above. They are commendably clear and concise. It is greatly to be hoped that they will be implemented.

Of the 66 papers presented to the Conference and listed in the Summary Report under review, Nos. 1, 10, 13, 19, 20, 36, 37, 38, 41, 45, 46, 48, 51, 53, 54, 56, 62, 63, and 64 are of special interest. The value of such papers to the discussions and contacts of each Conference would be greater if they reached the prospective delegates six months before the Conference.

NOTICES

The Scots Pine. An Introduction to Forestry. By HARRY WATSON. Oliver and Boyd, 1947. 82 pp. Price 5*s*. (Foreword by the Deputy Director-General, Forestry Commission, Mr. A. H. Gosling.)

THIS plain unvarnished tale, handsomely illustrated by numerous photographs, is an introduction to forestry written for the young. The author begins with a general account of Scots pine, how it is made, how it works, and how it reproduces. Nursery work, planting, and tending follow, with emphasis on what is done but salted throughout with biological principle. Felling, extraction, and utilization complete the brief account except for a final telling appeal to the constructive imagination of the young patriot. The author is to be congratulated on his enthusiasm and competence.

A. S. W.

Woodland Mosses. By H. WATSON. Forestry Commission Booklet No. 1. H.M.S.O., 1947. Price 2*s*.

THIS, according to the advertisement on the back page, is the first of a series of booklets, published by the Forestry Commission, 'which are straightforward accounts of subjects important in forestry'. Anyhow, it is a brief account of twenty mosses selected because in some parts of the country they are common and, for mosses, conspicuous. Short descriptions adequate to identify the moss within the selected twenty are accompanied by photographs illustrating a dried specimen and the moss forming a 'turf' in the field. The latter set is good for its purpose, the former a reminder that the general appearance of the moss when dry is often very different from what it is when wet. A brief introduction draws the beginner's attention to the life-history and the elementary morphology of mosses. The author correlates the occurrence of the selected mosses with the state of the humus in the soil.

A. S. W.

Fire Control Notes, Vol. 8, No. 4. October 1947. Forest Service, U.S. Department of Agriculture, Washington.

THE common hospital gauze masks, moistened with water, together with a plain light goggle are equally as efficient as and more comfortable in use than any of the more complex respirator masks for fire-fighting in heat and smoke. To train lumber workers in 'safe smoking' meets with better response than impossible-to-control restrictions and has reduced smokers' fires from 13 to 2 in analysed cases. Statistics will not put out fires and those compiled solely with the objective of padding official reports indicate lack of administrative vision. The true value of fire statistics and their correct collection and presentation are their use in formulating fire-protection policy. Has any Forest Service outside the United States even begun to consider this? War-time shortages in man-power of the Ranger services were eased by recruiting and training both boys and girls from high schools. Here is practical training which will provide the townsman with forest interests and forest-mindedness throughout his life. More extemporized machines (including the amphibian 'Weasel'), waterproofed plywood water tanks, improved jet and mist pump

nozzles, and the advantages of 'wet water' over ordinary water: all these go to build up an interesting and variegated number.

One does wish, however, that the constitution of 'wet water' had been specified and would like to know what is 'goop' as a kindling agent for slash burning. An exploratory study to correlate increasing and waning sun-spot cycles with climatic fire hazard is suggestive but not completely convincing.

G. B. R.

Extracts from *Forestry Abstracts*

THE following items are reproduced by permission of the Imperial Forestry Bureau, Oxford, from their quarterly journal. They include matter of special interest to British foresters, not reviewed or noticed elsewhere in *Forestry*.

Forestry Abstracts is available to British residents at 20*s*. per annum, including postage, from the Imperial Agricultural Bureaux, Central Sales Branch, Agricultural Research Building, Penglais, Aberystwyth, Wales.

Grateful acknowledgements are recorded for the permission to reproduce the items.

Vol. 9, No. 1, 1947

[14]. 07.1 (73). Vitas, G. *American Forestry Schools must come out Swinging. J. For.* 45 (3), 1947 (159–71).

The writer discusses the future of the forestry profession in the United States, the prospects of employment for the unprecedented number of students now enrolled at the forestry schools, and the desirable changes in curriculum and outlook of those schools if they are to fit the students for employment. He stresses the necessity for adapting forestry education to the training of practitioners in farm forestry, public relations, business administration, marketing, consultant forestry, surveying, housing construction, real-estate dealing, commercial nurseries, tree surgery, sawmilling, &c. It is essential that the teaching staff should be in continuous touch with practical forestry, business, &c.

[16]. 07.1 (73). Guise, C. H. *Statistics from Schools of Forestry for 1946: degrees granted and enrollments. J. For.* 45 (3), 1947 (174–80).

At the beginning of the academic year 1946–7, the number of undergraduates enrolled in American forestry schools was 7,070, an increase of 5,537 on the previous year and the highest number that the schools have ever had, the previous record being 6,067 in 1937–8. Considerable concern is felt about their possibilities of employment.

[33]. 09.7 (43.1–5): 90. Kircher, J. C. *The Forests of the U.S. Zone of Germany. J. For.* 45 (4), 1947 (249–52).

The forests of the U.S. zone of Germany, which represent 36 per cent. of the forest area of present Germany, cover 8,850,000 acres or about one-third of the total area of the zone. These forests, which are 30 per cent. hard-woods and 70 per cent. conifers, have mostly been planted, though natural regeneration is also used. Much Spruce and Pine was planted in pure stands 50–100 years ago, but younger stands generally have a mixture of hardwoods to keep up the quality of the soil. Even-aged and two-aged stands are the rule. Markets are so well developed that practically the whole tree can be utilized. Thinnings starting at 1 in. d.b.h. can be made to pay for themselves. Stands are usually worked over at 3- to 5-year intervals, starting at about 30 years, and rotations are relatively long (80–200 years). Growth figures compiled just before the war showed that state forests were growing at the rate of 455 bd. ft. per acre, large private holdings at 333 bd. ft.,

medium-sized ones at 242 bd. ft., and small ones not much over 100 bd. ft. The Germans state that the most economical unit of management is between 5,000 and 10,000 acres, and the figures support this view. Such an area allows the employment of a high-grade technical forester to manage the forest.

The U.S. Military Government is at present making a complete inventory of the timber resources of the zone, which will give volumes by age-classes and size, growth, and other information. At the same time, management plans are being brought up to date and those destroyed during the war are being replaced. Similar surveys are being made in the other three zones and when all are complete a forest cutting budget will be established to take effect from October 1947. The Allied policy will probably provide for shortening timber rotations and for the systematic removal of all timber above the new rotation age.

[104]. 12.11.22: 12.25: 12.11.3 (485). KIELLANDER, C. L. *Om barrträdsförädling och barrträdsympning.* [*The breeding and grafting of conifers.*] *Repr.* from *Svensk PappTidn.* Nos. 23 and 24, 1946. pp. 16. [Sw.e.]

A brief, illustrated review of the conifer-breeding work in progress at Ekebo and the various branch stations of the Swedish Forest Tree Breeding Association, including a special section describing with explanatory photographs the technique of grafting Norway Spruce, Scots Pine, and Larches.

[128]. 12.19: 02.1: 61. TANSLEY, A. G. *Introduction to Plant Ecology: a Guide for Beginners in the Study of Plant Communities.* George Allen & Unwin Ltd., Museum Street, London. 1946. pp. 260. Price 8*s.* 6*d.*

The present work is a thoroughly revised version of the author's *Practical Plant Ecology* originally published in 1923. Not only has the text been brought up to date, but the balance of the book has been to some extent changed. The general exposition of the subject has been added to and strengthened, treating concepts relating to plant communities more fully and defining the plant formation in accordance with *The British Islands and Their Vegetation*; the section on Life Forms has been expanded. The practical side of field ecology is represented by new sections on methods of vegetation survey and photography, but instructions in soil analysis are restricted to rough field tests. There is a bibliography of 14 pages and a few line text-figures but no photographic illustrations.

[146]. 12.19.2 (41.5): 12.19.4: 11.49. McEVOY, T. *The Vegetation of Irish Native Woodland. Irish For.* 3 (2), 1946 (84–92).

The main climax types in Ireland are as follows: (*a*) *Oakwoods on acidic soils*—on Old Red Sandstone, Metamorphic, Cambrian, Silurian, and granitic rocks. Sessile Oak is always dominant. There are three main subdivisions: (i) *Vaccinium* type; (ii) *Luzula* type; (iii) Fern type. (*b*) *Woods on calcareous soils*, e.g. limestone and basalt; these soils account for two-thirds of the country but, owing to their greater agricultural value, few natural woods exist on them to-day. There are again three subdivisions: (i) Oak/Ash on deep soils; (ii) Ash on shallower soils; (iii) Hazel scrub on bare limestone pavements. In addition, there are two more or less permanent types dependent on high water-table in the soil: (*a*) Alder wood, with or without Ash; (*b*) Birch wood. These associations are described in some detail.

[174]. 13.15: 13.2: 22.8: 45.3. KOSTER, F. *Vogels en hun betrekkingen tot het bosch.* [*Birds and their relations to the forest.*] *Ned. Boschb.-Tijdschr.* 17 (1), 1944 (1–16). [Du.]

A rough inventory of the birds of woods on the Schovenhorst estate, Veluwe, gave a total of fifty-two breeding species. Fourteen species nested in young, mainly coniferous

woods up to about 15 years old; only eight species in pure Scots Pine about 35 years old; nearly forty species in 50-year-old, and about forty-five species in 80- to 100-year-old mixed, mainly coniferous forest.

The author agrees with T. C. Oudeman's view that any considerable increase in the permanent bird population depends on the establishment of mixed forest, preferably of hardwoods. The planting of berry-bearing shrubs and small trees is also strongly recommended.

[185]. 2: 12.25 (41.5): 31.8. Clear, T. *The Production of High Grade Softwood Timber in Ireland. Irish For.* 3 (2), 1946 (75–83).

The principal defects of Irish-grown softwoods are knots, excessive ring width, and relative immaturity. Measures recommended for control of these defects are close planting and early and frequent light thinning. The best timber is often produced by co-dominants or 'half-shade' trees, the result of beating up. Early live-pruning is recommended for these.

[201]. 21.12: 12.26–8: 12.11.3. Chevalier, A. *Un* Eucalyptus *résistant au froid venu probablement par mutation.* [*A cold-resistant Eucalypt produced probably by mutation.*] *Rev. int. Bot. appl. Agric. trop.* 26 (283/284), 1946 (232–4). [F.] P.R.

A tree which appeared about 20 years ago in sowings of locally grown seed at the Parc de la Fauconnière, near Cherbourg, was apparently killed by frost in the winter of 1929, but in the following spring put out two basal shoots which developed into two flourishing trees. One was cut by the Germans, the other survives and is about 15 m. high and 99 cm. in girth at 1 m. above ground level. For some 10 years this tree has given vigorous natural seedlings which have suffered no frost damage in the recent severe winters. It is surmised that a bud mutation took place in the frost of 1929. The new form is named *E. coccifera* var. *favieri* n. var. and morphological differences from type are noted. It grows near the sea on dry, siliceous, heathy ground and might well be worth trying for coast afforestation in N.W. France.

[260]. 24.51: 12.25: 44.3. Bauer, B. *Följden av grankvistning.* [*Consequences of pruning Norway Spruce.*] *Skogsägaren* 21 (3), 1945 (52–3). [Sw.]

A case in which stem rot occurred in almost every other tree of a 50- to 55-year-old stand of *Picea abies* is ascribed to and used as a warning against the pruning of this species.

[261]. 24.51: 12.25: 12.26–8. *Angående kvistning.* [*A note on pruning.*] *Skogsägaren* 21 (4), 1945 (66). [Sw.]

Agreement is expressed with Bauer's warning against the pruning (at least so far as live branches are concerned) of Norway Spruce [see preceding abstract], but it is pointed out that live pruning can be recommended for Oak (*Quercus robur* s.l.] and Scots Pine [*Pinus sylvestris*]. Pruning should be done before the buds break. With Oak, it is important not to remove too much of the foliage at once, but the author's experience with Scots Pine in various parts of Sweden indicates that this species can be pruned without risk, provided that the number of whorls left in the crown is not less than the height of the tree in metres. Pine branches should be pruned flush with the stem: in Oak a short stub should be left —about as long as the diameter of the branch—and the cut should be at right angles to the axis of the branch.

[262]. 24.51: 12.25: 46. Helmers, A. E. *Pruning Wound Healing on Western White and Ponderosa Pine. Res. Note Nth. Rocky Mt. For. Range Exp. Sta.* No. 45, 1946. pp. 6.

Pruning which removed the branch collar resulted in considerably faster wound healing than pruning which left the branch base intact, although it made a larger wound. On dead branches, close pruning resulted in a 16 per cent. greater average area of healing and on live branches 8 per cent. Wounds from small branches healed faster than those from large branches, particularly in the denser stands where diameter growth was slow. Wounds resulting from the removal of live branches healed faster than wounds from dead branches. Healing was more rapid on the fast-growing trees of open stands of White Pine, despite the larger size of the wounds, than on the slow-growing trees of the dense stands. No appreciable differences were evident in the extent of wound healing between autumn and spring pruning. These experiments indicate that the optimum conditions for rapid wound healing result from close pruning of small live branches on rapidly growing trees.

[263]. 3 (73): 07.2. Arneson, G. N. *Some Observations on Forest Products Research. J. For.* 45 (3), 1947 (193–7).

The writer considers that there is a tendency of American forest products research laboratories to over-publicize results, leading to an erroneous estimation of the value of such research, which actually consists largely in long-term unspectacular research into fundamental problems. Many of the most loudly proclaimed of recent results, e.g. compreg, heat-stabilized wood, urea-plasticized wood, lignin plastics, &c., are still only practicable on a laboratory scale. Discoveries such as those of fibre saturation and moisture equilibrium of wood, the determination of properties of different species, &c., are in reality much more important.

[320]. 31.43: 13.2 (410). Kaufman, R. R. U. *Notes on the Occurrence of* Hylotrupes bajulus *L. (Col., Cerambycidae) in the British Isles. Ent. mon. Mag.* 83 (993), 1947 (37–40).

Hylotrupes bajulus is a casual importation and is not an indigenous British species. Most of the British records refer only to isolated examples taken from timber in coastal, industrial and metropolitan areas where imported softwoods are likely to be found in bulk.

[448]. 33.51 (410). *The Case for Home-grown Pit Props. J. Land Agents' Soc.* 46 (5), 1947 (117–21).

The writer analyses the costs of producing pit-props in Britain for the home market in the light of the revised prices. He concludes that the use of thinnings for unpeeled props is an economic proposition, but that the extra charge for peeled props is not sufficient to cover the cost of peeling. A problem which still awaits solution is the utilization of very rapidly grown thinnings, which have not the requisite degree of strength. It is suggested that this difficulty might be met by increasing the ratio of diameter to length of pit-props.

[537]. 44.3: 12.25: 12.21: 23.51. Vloten, H. van. Fomes annosus *Fr. in onderplantingen.* [Fomes annosus *in underplanted stands.*] *Ned. Boschb.-Tijdschr.* 15 (7), 1942 (337–8). [Du.]

In stands of Scots Pine underplanted with conifers such as Douglas Fir and Japanese Larch there is a danger that the new crop may be infected from stumps of the overwood; these, in the author's opinion, should be removed before underplanting is done.

[653]. 76: 22.22: 12.26–8: 33.6: 33.55. Durham, C. B. *Hazel Underwood. J. cent. Landowners' Soc.* 26, 1947 (15–18). X.

Hazel underwood now fetches high prices (in England) mainly because it is used for crates for packing pottery for export, owing to the shortage of box boards and cartons. Crate rods are required in four sizes:

20	in a bundle,	over 10 ft. long,	1½–2 in.	diam. at butt.
40	,,	over 12 ft. long,	1–1½ in.	,, ,,
75	,,	10–12 ft. long,	½–1 in.	,, ,,
100	,,	7–9 ft. long,	½ in. or less	,, ,,

The rods are sold by the load of about 4 tons. The price to be derived from an acre of Hazel is about £63. 10*s*. on a yield of 250 bundles of crate-rods (£50), 200 bundles pea-sticks (£6), 25 bundles of bean-rods (£2. 10*s*.), and clothes-props, crate heads, &c. (£5). The cost of production per acre is: cutting, sorting, and tying 250 bundles, £18. 15*s*., bundling pea-sticks, £2. 10*s*., bundling bean-rods, £1. 5*s*., sundries £1. 10*s*. If as much as £22. 10*s*. is paid for an acre of underwood, this leaves a profit of £17 per acre.

Vol. 9, No. 2, 1947

[728]. 11.44 (421–8). Pearsall, W. H. *Leaf-fall in Hertfordshire Woodlands. Trans. Herts. Nat. Hist. Soc.* 22 (3), 1945 (97–8). O.R.S.

Data are given showing the amount of dead material (leaves and twigs) falling per square metre in coppiced woods with mature Oak (*Quercus sessiliflora*) standards near Stanstead-bury, Herts., during October to December. The figures suggest that the soil gains at least 1,500 g. of organic matter per sq. m. during this period.

[745]. 11.62.31: 91.3 (931): 21.0: 12.25. Smith, J. L. H. *Exotic Forests and Runoff. N.Z. J. For.* 5 (3), 1946 (231–2).

Extensive 16-year-old plantations of *Pinus radiata* in the Auckland Conservancy are said to be drying up the streams rising in the catchment area of the forest. Under the heavy canopy, the natural ground cover of Manuka scrub has almost completely given way to a thick layer of needles. In a neighbouring catchment planted at the same time with *P. laricio*, where the canopy was not yet sufficiently dense to suppress the scrub entirely and much less litter has accumulated, the rise in stream-flow, after rain, began at the same time but was more rapid and reached a greater height. At Tairua Forest on the Coromandel Peninsula, where an area of low bracken and Manuka was planted with *P. radiata* about 15 years ago, a similar drying-up of streams is reported.

[760]. 12.11.3 (68): 07.2. Sherry, S. P. *The Potentialities of Genetic Research in South African Forestry.* [Department of Forestry, Pretoria.] 1947. pp. 11. [5th British Empire Forestry Conference, Great Britain, 1947.]

Special conditions applying in South Africa are discussed in the light of their influence upon present and future genetic policy, and the need for a planned programme of genetic research in conjunction with post-war State afforestation is emphasized. Clinal forms of *Pinus taeda* from specific localities in the Southern United States and of *P. pinaster* from Portugal are shown to be superior, under South African conditions, to other clines of these species. Mother-tree selection in *P. radiata* has given promising results, and it has been found possible to isolate vigorous individuals, mainly hybrids (*P. sondereggeri*), by nursery selections of *P. palustris* for vigour. Results of breeding in Pine and tan Wattles are outlined, and data from field plantings of rooted cuttings of *P. radiata* are presented. In

conclusion, suggestions are made for a programme of forest genetic research in South Africa. *Author's abstract.*

[761]. 12.11.3: 12.25 (68). *Seed Provenance. Rep. Dep. For. S. Afr. 1946*, 1947 (6).

Tests of geographical strains from fifteen sources of *Pinus taeda* and five sources of *P. caribaea* have been in progress since 1937 in various parts of the Union of S. Africa. Marked and consistent differences in vigour are now discernible between various strains of *P. taeda*, maximum differences in mean height in some trials approaching 100 per cent. Differences in strains of *P. caribaea* in this project are hardly noticeable, but a strain introduced from British Honduras in 1928 and established at Dukuduku in Zululand shows conspicuous superiority over the best strains used for local afforestation, its mean annual increment at 17 years of age being more than twice that of the best strains from the United States available locally. In 1941 precocious seedlings of *P. palustris* were noticed in the nursery at Kwambonambi and a project was established to test their subsequent growth in comparison with normal seedlings. Four years and 8 months later the precocious seedlings showed an average height of 20·4 ft. and a mean d.b.h. of 5·1 in. compared with 13·9 ft. and 3·2 in., respectively, for controls.

[762]. 12.11.3: 12.25 (68). Rycroft, H. B., and Wicht, C. L. *Field Trials of Geographical Races of* Pinus pinaster *in South Africa.* [Department of Forestry, Pretoria.] 1947. pp. 12+plates. [5th British Empire Forestry Conference, Great Britain, 1947.]

Replicated field trials with stocks of *Pinus pinaster* Soland. from known localities in Europe and North Africa were established in South Africa from 1934 to 1936. The objects were to determine differences due to geographical races and to ascertain which stocks were most desirable for afforestation. The trials are described and data derived from an interim enumeration are analysed. Some data from a few older stands of known origin are also referred to. The investigation indicates that six races are represented in South Africa, namely, Corsican, Esterel, Landes, Luccan, Moroccan, and Portuguese. The Portuguese race is proving superior to all others in rate of growth and density of timber and its use in preference to all others for afforestation in this country is confirmed. *Author's summary.*

[763]. 12.11.3 (71): 12.25. Farrar, J. L. *Forest Tree Breeding in Canada.* Dominion Forest Service, Ottawa. 1947. pp. 17. [5th British Empire Forestry Conference, Great Britain, 1947.]

The history of organized research into forest tree breeding in Canada is briefly reviewed, and a more detailed account (citing literature) is given of the work carried out in and around Ottawa and at the Petawawa Forest Experiment Station. The Sub-committee on Forest Tree Breeding considers that the following projects are of major importance: (1) Production of White Pine of good quality and rapid growth, resistant to blister rust and weevil. (2) Production of rapid-growing, high-quality Spruce for both pulpwood and lumber. (3) Production of hardy, drought- and disease-resistant Poplars for shelterbelt planting in the western prairies. (4) Production of rapid-growing, disease-resistant, high-quality Poplars for pulpwood, match stock, and veneer. Progress reports are given on these projects. Quotation is made from unpublished reports by Heimburger on provenance tests on strains of *Picea abies* from twenty localities in Europe and five plantations in Canada [cf. *For. Abstr.* 7 (No. 88)]. Those from northern Norway are heterogeneous and show abnormalities in growth form, while those from Latvia are homogeneous and quite normal in growth form. In general, strains from the regions east of the Baltic have produced very satisfactory stock. Seed from certain plantations near Grand'

Mère, Quebec, are superior in many respects to seed of any European origin tried so far. *P. obovata* from Latvia ranks with the better *P. abies*. *P. asperata* from planted specimens in France also shows promise. There seems to be considerable variation within strains of *P. abies*; certain plants from one Rumanian strain are outstandingly vigorous. In almost all strains some plants are attacked by *Pissodes strobi* while others near by are unaffected.

Strain tests of native species of Spruce are also in progress. Heimburger has observed that in *P. glauca* the marked differences in morphological characters found in the mature material in the Rocky Mountains have not been evident in their progeny. These strains have shown resistance to late spring frosts in spite of their early spring growth. The progeny of *P. mariana* growing in uplands are more drought-resistant and easier to transplant than the progeny of trees of the same species growing in swamps; they also differ in growth form and morphological features. This suggests the existence of ecotypes within the species. The upland ecotype is a tree with considerable promise, being resistant to spring frosts and fairly fast growing.

[766]. 12.11.3: 12.26–8. Johnsson, H. *Interspecific Hybridization within the genus* Betula. *Separate* of *Hereditas, Lund* 31, 1945 (163–76).

The experiments were carried out by means of bottle-grafting, which is described in some detail. Interspecific crossing experiments between *Betula verrucosa* and other species are reported. The combinations *B. verrucosa* × *B. papyrifera* and *B. verrucosa* × *B. japonica* are fertile and vigorous. Interspecific crossing experiments between *B. pubescens* and other species produced fairly fertile hybrids and the cross *B. pubescens* × *B. papyrifera* showed heterotic vigour. Species of the section *Albae* are extremely, if not completely, sterile in combinations with species of the section *Costatae*. Crosses between the two *Albae* species *B. pubescens* and *B. verrucosa* are also extremely sterile. The results obtained are discussed, special stress being laid on the lack of agreement between the extreme sterility in the cross *B. pubescens* × *B. verrucosa* and the general conception that the numerous intermediate forms between these two species are of hybrid origin.

[816]. 21.0 (68): 12.25: 56: 23.24.3: 24.2: 24.51: 76. Craib, I. J. *The Silviculture of Exotic Conifers in South Africa.* [Department of Forestry, Pretoria.] 1947. pp. 35. [5th British Empire Forestry Conference, Great Britain, 1947.]

A brief outline of the background in current silvicultural policy in South Africa is given. Methods of afforestation are discussed and recommendations for the amendment, where necessary, of present practice regarding initial espacement and pruning are made. Data on the effects of growing-space upon natural competition, increment, and ring width [cf. *For. Abstr.* 9 (No. 920)] are presented. These show that under South African conditions suppression of the predominants commences at an early age for a wide range of tree densities and the time of its onset is not markedly affected by site or species; also that, despite this suppression, ring widths are apt to be large in the predominants during youth, irrespective of tree density. The data show, moreover, that maximum monetary returns from early thinnings are likely to be derived from initial espacements of 9 × 9 to 12 × 12 ft.

Data are given which show that the longer thinning to a given density of growing stock is delayed, the greater will be the loss in total volume increment thereafter. Upon the basis of the increments of unthinned stands growing at various densities, extrapolated to maturity, it is shown that the financial returns from relatively heavily thinned stands are likely to be far greater (almost double) those of relatively lightly thinned stands.

Reference is made to the remarkable vigour of the Portuguese strain of *Pinus pinaster* [cf. *For. Abstr.* 9 (No. 762)] relative to other strains, and to the reasons why *P. pinaster* should,

in future, receive the same silvicultural treatment as other medium-fast-growing Pines like *P. taeda* and *P. caribaea*. The paper concludes with a summary of recommendations made to amend those proposed by the writer in 1939. [Cf. *For. Abstr.* 1 (165).]

[846]. 23.24: 12.26–8 (410). Le Sueur, A. D. C. *The Replanting of Beech Woods. Ctry. Life, Lond.* 96 (2479), 1944 (118–19). O.B.

The difficulties attending the satisfactory re-establishment of Beech woods in Britain by natural regeneration are briefly discussed. Except in the case of woods managed chiefly for amenity purposes or those situated on exposed slopes, propagation by means of transplants is generally preferable. The practice of including conifers in Beech plantations to cheapen costs and provide earlier returns is almost universal. A preponderance of conifers decreases the power of selection for the final crop, and a 50 per cent. mixture should not be exceeded.

[849]. 23.24.3: 12.25. Munger, T. T. *The Spacing in Plantations. For. Res. Notes Pacif. Nthwest. For. Range Exp. Sta.* No. 34, 1946 (3–4).

Data showing the effects of different spacings (4×4, 5×5, 6×6, 8×8, 10×10, and 12×12 ft.) on the growth of Douglas Fir at the Wind River Experimental Forest during the first 20 years of stand history.

The following observations were made: (1) The average diameter increases with width of spacing, and in the 12×12 ft. plot is about twice that on the 4×4 plot. (2) The wider the spacing, the greater the average height of all trees. (3) The heights of dominant trees are more nearly alike for all spacings than are the average heights of all trees. (4) The closer the spacing, the greater are the basal area and cubic volume. (5) There is a progressive increase in crown width from close to wide spacing. (6) The diameter of the limbs at breast height is progressively greater with wider spacing. (7) The growth of bracken, annuals, and shrubs is much greater with the wide spacing.

The relative advantages of close and wide spacings are very briefly discussed.

[877]. 27 (410). Laurie, M. V. *The Treatment of Derelict and Devastated Woodlands in Great Britain.* H.M. Forestry Commission, London. 1947. pp. 6. [5th British Empire Forestry Conference, Great Britain, 1947.]

The restoration of derelict and devastated woodlands, together with areas of uneconomic coppice, to a productive state, is a major problem facing British forestry. Such woodlands are probably over half a million acres in extent, and occur mainly in the Midlands and the South of England in detached blocks under private ownership. They have reached their unsatisfactory condition through continued neglect, followed by intensive exploitation during the war of 1939–45. The methods of replacement that are discussed include natural regeneration, conversion of suitable coppice areas to high forest, underplanting of scrub or pole crops, complete clearance and replanting, and partial clearance by the strip or group methods. *From author's summary.*

[920]. 31.23: 12.25 (68): 55: 56. Turnbull, J. M. *Some Factors affecting Wood Density in Pine Stems.* Dept. of Forestry, Pretoria. 1947. pp. 22. [5th British Empire Forestry Conference, Great Britain, 1947.]

Average data accumulated chiefly from dissection of twenty to thirty stems (of *Pinus patula*, *radiata*, and *taeda*) from each of five different sites in South Africa are used in an attempt to show that variations in wood density in Pine stems, hitherto regarded as fortuitous, are actually systematic. Analysis of the data shows that whereas aggregate wood density, or

the mean density across entire transverse sections, is, in normal circumstances, directly correlated with rate of growth, the density of wood formed in any particular year is directly proportionate to a function of age. The influence exercised on density by aspect, edaphic factors (with special reference to moisture), and seed selection is also briefly discussed. A method of research based on the density/age relationship is suggested for use in further attempts at isolating the environmental factors that determine wood density.

Although in any particular year, rate of growth exerts no influence on wood density, aggregate density does vary, within the limits of silvicultural practicability, according to the width of wood imposed at different stages in the stem's development. No apprehension need be entertained regarding the production of light wood due to wide espacement in the later parts of rotations. If the rate of growth in the earlier portion of the rotation has been high, the volume of heavy wood produced will be relatively low, but its absolute volume will be as great as, or even greater than, it would have been had the rate been low, and the extra volume of light wood may be regarded as a bonus. In other words, production of a large volume of heavy wood entails acceleration of growth during that portion of the rotation in which heavy wood is naturally produced, and the larger the core of light wood upon which it is imposed, the higher will that volume in individual stems be. *From author's summary and conclusions.* [Cf. *For. Abstr.* 9 (Nos. 816, 921).]

[988]. 33.1: 34.6: 33.7: 07.7. *Le briquetage des sciures.* [*Briquetting sawdust.*] *Rev. Bois Appl.* 1 (12), 1946 (34–5). [F.] P.R.

A description, with illustrations, of a Swiss machine for making briquettes from sawdust, shavings, and charcoal dust. The machine can produce 8 tons of briquettes in 8 hours with six to eight workers.

[1107]. 33.32.3. Winters, D. W. *Feltwood in Forest Management. J. For.* 45 (6), 1947 (447–8).

Wood fibre is now widely used in the manufacture of roofing felts. Wood of a lower grade than that required for pulpwood is acceptable; almost any species may be used, the wood need not be peeled, and knots are no defect.

[1114]. 33.36.1: 33.31. *Le créosite.* ['*Creosite*'.] *Rev. int. Bois* 14 (119), 1947 (118–20). [F.]

'Creosite' (patent owned by the Sté. Ame. Le Créosotage Universel, Charleroi), is a supercreosote of high permanent toxicity, derived from the distillation of tar oil, and applicable by cold soaking, which has been widely used in Belgium for 25 years past. Its toxicity is notably superior to that of ordinary creosote (it contains 25 per cent. of phenols compared with 7–8 per cent. in ordinary creosote) and so is its fluidity. Permanence of toxicity is ensured by the non-volatility and water-insolubility of its chemical constituents.

[1163]. 33.51: 31.27: 32.82: 32.24. Guinier, P.-H. *Note sur l'influence possible des conditions de conservation et de la saison d'abatage sur les propriétés mécaniques des étais de mine.* [*Note on the possible influence of storage conditions and felling season on the mechanical properties of pit props.*] *Les techniques du bois* 2, 1947 (103–4). [F.]

[1275]. 44.3: 12.25: 46: 32.7. Wright, E., Rhoads, A. S., and Isaac, L. A. *Decay Losses following Logging Injury in Partially Cut Stands of Western Hemlock and Sitka Spruce. Timberman* 48 (10), 1947 (52, 54, 72, 74, 76). [Pacific Northwest Forest and Range Experiment Station.]

The first report on this project was made in 1944 [see *For. Abstr.* 6 (p. 114)]. The present paper briefly summarizes results of the 1945 studies. About half the residual trees injured

by logging became infected by wood-rotting fungi in a period varying from 5 to 32 years. Growth rate and rate of decay varied on different areas and there was no apparent relationship between growth rate and the amount of decay present. Decay following logging injury amounted in Western Hemlock to 41 per cent. of the calculated gross increment since logging, and in Sitka Spruce to 43 per cent. Injuries examined were of three main types: (1) trunk wounds, most of which are basal, (2) top breakage, (3) sunscald following partial cutting. The most frequent rot in Western Hemlock was caused by *Fomes annosus* (50 per cent. of the decay associated with trunk wounds) and that in Sitka Spruce by *F. pinicola* (60 per cent. of decay volume). Decay caused by the former fungus is somewhat less serious than that caused by the latter, since affected wood can be used in the manufacture of low-grade paper.

A reduction of decay loss in partial cutting can only be effected by a reduction in the amount of logging injury, which could probably be secured by the use of lighter machinery or of horses in skidding, by confining skidding as much as possible to main skid roads with a minimum of curves, by avoiding skidding in the spring 'bark-slipping' season when trees are most susceptible to injury, and by taking out severely injured trees at the close of each cutting operation. It was apparent that lighter cuts resulted in less logging injury, less sunscald, and less loss by windthrow.

CONTENTS

The Place of Compound Interest in Forest Finance. By W. E. HILEY . 137

Forest Fire Protection in Germany. An Examination in Regierungs Bezirk Lüneburg (914 Military Government). By G. B. RYLE . . . 141

The Effect of Atmospheric Humidity on the Development of Fires. By J. BRYAN 146

Scots Pine Regeneration in a New Forest Inclosure (*Pinus sylvestris* L.). By E. W. JONES 151

Volume Estimation of Standing Timber by Sampling. By D. J. FINNEY . 179

Behaviour of Corsican Pine Stock following Different Nursery Treatments (*Pinus nigra* var. *calabrica* Schneid.). By M. C. RAYNER . . . 204

Preliminary Note on a Disease of Sitka Spruce in Cairnhill Plantation, Durris, Kincardineshire (*Picea sitchensis* Carr.). By E. V. LAING . 217

Pissodes Validirostris Gyll., In Shoots of *Pinus sylvestris* L. By MYLES CROOKE 221

Society's and Other News 227

REVIEWS

Breaking New Ground (GIFFORD PINCHOT). By G. B. RYLE . . . 233

The Earth's Face (Landscape and its Relation to the Health of the Soil) (EHRENFRIED PFEIFFER). By SIR HAROLD GLOVER 234

Handbook of the Trees of the Northern States and Canada (ROMEYN B. HOUGH). By F. K. MAKINS 234

Timber, its Structure and Properties (H. E. DESCH). By B. J. RENDLE. . 235

Decay of Timber and its Prevention (K. ST. G. CARTWRIGHT and W. P. K. FINDLAY). By W. R. DAY 236

Über die Physiologie ligninabbauender Bodenhymenomyzeten. Studien an Schwedischen Marasmius-Arten (GÖSTA LINDEBERG). By IDA LEVISOHN 238

Der Einfluss von Waldstreuextrakten auf das Wachstum von Bodenpilzen, mit besonderer Berücksichtigung der Wurzelpilze von Bäumen (ELIAS MELIN). By IDA LEVISOHN 239

Fifth British Empire Forestry Conference. Great Britain, 1947. Summary Report, Resolutions and Reports of Committees. By THE EDITOR . 241

NOTICES

The Scots Pine. An Introduction to Forestry. By HARRY WATSON . 246

Woodland Mosses. By HARRY WATSON 246

Fire Control Notes, Vol. 8, No. 4, October 1947. (Forest Service, U.S. Dept. of Agriculture, Washington.) 246

Extracts from *The Forestry Chronicle* and *Forestry Abstracts* . . 247

Printed in Great Britain at the University Press, Oxford, by Charles Batey, Printer to the University